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SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS 1972-1973, THIRD ANNUAL ISSUE

COLORADO STATE UNIVERSITY

PREPARED FOR
ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF WATER RESOURCES RESEARCH

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Research related to the quality of irrigation return flow is being conducted at numerous institutions throughout the western United States. Related work is also underway at other institutions in the United States, as well as other portions of the world. Approximately 100 sources of material have been searched for articles pertinent to the National Irrigation Return Flow Research and Development Program. These articles describe water quality problems resulting from irrigated agriculture, potential technological solutions for controlling return flows, recent research pertinent to return flow investigations, and literature associated with institutional constraints in irrigation return flow quality control. This bibliography contains 820 abstracts.

This third annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS covers publications printed in 1972 and 1973. ~~This report was submitted in fulfillment of Grant Number R-800426 under the sponsorship of the Office of Research and Monitoring, Environmental~~ Protection Agency (EPA).

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SELECTED IRRIGATION RETURN FLOW
QUALITY ABSTRACTS 1972-1973

Third Annual Issue

by

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Grant No. R-800426
Program Element 1BB039

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ABSTRACT

Research related to the quality of irrigation return flow is being conducted at numerous institutions throughout the western United States. Related work is also underway at other institutions in the United States, as well as other portions of the world. Approximately 100 sources of material have been searched for articles pertinent to the National Irrigation Return Flow Research and Development Program. These articles describe water quality problems resulting from irrigated agriculture, potential technological solutions for controlling return flows, recent research pertinent to return flow investigations, and literature associated with institutional constraints in irrigation return flow quality control.

The first annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS covered publications printed in 1968 and 1969, while the second annual issue lists publications printed in 1970 and 1971. This third annual issue lists publications printed in 1972 and 1973. This report was submitted in fulfillment of Grant Number R-800426 under the sponsorship of the Office of Research and Development, Environmental Protection Agency.

Key Words: Fertilizers, Irrigated Land, Irrigated Systems, Irrigation Water, Nitrates, Phosphates, Return Flow, Salinity, Water Pollution Effects, Water Pollution Sources, Water Quality Control.

FOREWARD

The third annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS has been compiled from approximately 100 sources of material covering calendar years 1972 and 1973. This compilation has attempted to include technological and institutional articles that would be pertinent to action programs regarding the control of water quality degradation resulting from irrigated agriculture.

The state-of-the-art report, "Characteristics and Pollution Problems of Irrigation Return Flow" prepared by the Utah State University Foundation contains a bibliography of articles pertinent to Irrigation Return Flow Quality Control. The references in this bibliography include articles and reports prior to 1968. The first annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS listed publications appearing in calendar years 1968 and 1969, while the second annual issue listed publications appearing in calendar years 1970 and 1971.

The third annual issue contains approximately 600 abstracts of documents published during calendar years 1972 and 1973. The abstracts have been placed into sections according to the category and subgroup classifications used by the Water Resources Scientific Information Center (WRSIC) as published in the report, "Water Resources Thesaurus." The abstracts have been forwarded to WRSIC for inclusion in their bi-monthly publication, "Selected Water Resources Abstracts."

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The typing of this final report has been the result of organization by Ms. Betsy Eakely and painstaking efforts by Martha Badgley.

The scope of this literature abstracting effort has been delineated jointly by the senior author and the Project Officer, Dr. James P. Law, Jr., Program Director, Agricultural Wastes Section, Treatment and Control Research, Robert S. Kerr Environmental Research Laboratory, Environmental Protection Agency, Ada, Oklahoma. The efforts of the Project Officer in meeting with project personnel numerous times to review the abstracting process have been very helpful and much appreciated.

Section I

WATER CYCLE

GENERAL (GROUP 02A)

72-73:02A-001
ROLE OF SUBSURFACE FLOW IN GENERATING SURFACE RUNOFF: I. BASE FLOW CONTRIBUTIONS TO CHANNEL FLOW,
Freeze, R. A.
Thomas J. Watson Research Center, Yorktown Heights, N.Y.
Water Resources Research, Vol. 8, No. 3, p 609-623, June 1972. 8 fig, 2 tab, 19 ref.

Descriptors: *Base flow, *Surface-groundwater relationships, *Mathematical models, *Numerical analysis, Unsteady flow, Saturated flow, Unsaturated flow, Water balance, Surface waters, Groundwater, Groundwater movement, Infiltration, Rainfall-runoff relationships, Hydrograph analysis.

The mechanism of base flow generation and the nature of watershed response in base flow dominant streams are examined with a deterministic mathematical model that couples three-dimensional, transient, saturated-unsaturated subsurface flow and one-dimensional, gradually varied, unsteady channel flow. The channel flow model uses the single step Lax-Wendroff explicit technique to solve numerically the full shallow water equations. The subsurface flow model uses the line sucessive overrelaxation technique to solve numerically the Jacob-Richards diffusion equation. The results of the simulations on a hypothetical basin suggest a wide variability in watershed response under the influence of variations in rainfall properties, antecedent moisture conditions, and saturated and unsaturated subsurface hydrogeologic properties. This evidence of a wide range of watershed response functions leads to skepticism toward black box rainfall-runoff correlations, the concept of basin linearity, and the rationality of hydrograph separation.

72-73:02A-002
ROLE OF SUBSURFACE FLOW IN GENERATING SURFACE RUNOFF: 2. UPSTREAM SOURCE AREAS,
Freeze, R. A.
Thomas J. Watson Research Center, Yorktown Heights, N.Y.
Water Resources Research, Vol. 8, No. 5, p 1272-1283, October 1972. 11 fig, 27 ref.

Descriptors: *Model studies, *Storm runoff, *Simulation analysis, *Rainfall-runoff relationships, *Subsurface runoff, Subsurface flow, Soil water movement, Surface-groundwater relationships, Mathematical models, Water level fluctuations.

Runoff simulation carried out with a deterministic mathematical model that couples channel flow and saturated-unsaturated subsurface flow provides theoretical support for runoff-generating mechanisms observed in the field. There are stringent limitations on the occurrence of subsurface storm flow as a quantitatively significant runoff component. Only on convex hillslopes that feed deeply incised channels, and then only when saturated soil conductivities are very large, is subsurface storm flow a feasible mechanism. On concave slopes with lower permeabilities, and on all convex slopes, hydrographs are dominated by direct runoff through very short overland flow paths from precipitation on transient near-channel wetlands. On these wetlands surface saturation occurs from below because of rising water tables that are fed by vertical infiltration rather than by lateral subsurface flow. These conclusions, when coupled with field observations that show classic Hortonian overland flow to be a rare occurrence in vegetated humid environments, have implications in planning field instrumentation networks, and in designing hydrologic response models.

72-73:02A-003
STOCHASTIC MODELING OF TEMPERATURE AND FLOW IN RIVERS,
McMichael, F. C., and Hunter, J. S.
Carnegie-Mellon University, Pittsburgh, Pennsylvania, Division of Sponsored Research.
Water Resources Research, Vol. 8, No. 1, p 87-98, February 1972. 12 fig, 2 tab, 9 ref.

Descriptors: *Time series analysis, *Stochastic processes, *Statistical models, *Water temperature, Discharge (Water), *Streamflow forecasting, Simulation analysis, Synthetic hydrology, Mathematical models.
Identifiers: *Stochastic models.

Forecast models using historical time series data for temperature and flow may be constructed by means of parametric time series models. The new methods and two examples of data illustrative of the iterative procedures necessary to construct a good forecast model are given. The daily water temperature and Ohio River discharge at Wheeling, West Virginia, for January 1, 1963-December 31, 1968, provide the raw material for the models. The methods are easily extended to other problems.

72-73:02A-004
APPLICATION OF THE CONVOLUTION EQUATION TO STREAM-AQUIFER RELATIONSHIPS,
Hall, F. R., and Moench, A. F.
New Hampshire University, Durham, Institute of Natural and Environmental Resources.
Water Resources Research, Vol. 8, No. 2, p 487-493, April 1972. 9 fig, 13 ref.

Descriptors: *Hydrologic equation, *Surface-groundwater relationships, *Mathematical studies, Equations, Base flow, Recession curves, Transmissivity, Infiltration, Recharge, Hydrogeology, Water level fluctuations, Discharge (Water), Diffusivity.

Flow and head variations in stationary linear stream-aquifer systems may be obtained through application of the convolution equation. Four highly idealized cases involving finite and semifinite aquifers, with and without semipervious stream banks, are considered. Equations for the instantaneous unit impulse response function, the unit step response function, and the derivative of the unit step response function are given for each case. Head fluctuations in the aquifer due to an arbitrarily varying flood pulse are obtained for the cases involving a finite aquifer with and without a semipervious stream bank. Flow in and out of the aquifer at the stream bank is determined for the same cases and demonstrates the value of the convolution equation in evaluating the base flow. Head variations, and to a lesser extent flow variations, are apparently relatively insensitive to variations in aquifer diffusivity.

72-73:02A-005
WATERSHED PHYSICS: SOIL VARIABILITY CRITERIA,
Rogowski, A. S.
Agricultural Research Service, Beltsville, Maryland, Hydrograph Laboratory.
Water Resources Research, Vol. 8, No. 4, p 1015-1023, August 1972. 2 fig, 5 tab, 27 ref.

Descriptors: *Unsaturated flow, *Hydraulic conductivity, *Mathematical models, *Soil water movement, *Variability, Statistical methods, Statistical models, Saturated flow, Groundwater basins.
Identifiers: *Watershed physics.

Variability criteria were developed for input parameters to the moisture characteristic and hydraulic conductivity models. The parameters include the water contents at air entry and at 15 bars as well as the hydraulic conductivity used in matching the predicted values with the experimental values at saturation. The available data suggest that the water contents at 15 bars and at air entry have a normal distribution whereas the hydraulic conductivity has a log normal distribution. The distributions of water contents and conductivities for different soil series with depth and over an area are illustrated. In watershed studies a soil may be considered uniform with depth or over an area if the coefficient of variation with respect to water content does not exceed 15% at 15 bars and 10% at air entry and the logarithmic standard deviation for hydraulic conductivity is less than log 2. If these conditions are met, the water contents at 15 bars and at air entry as well as the saturated conductivities may be averaged.

72-73:02A-006
A SIMULATED ENVIRONMENTAL MODEL OF TEMPERATURE, EVAPORATION, RAINFALL, AND SOIL MOISTURE,
Jones, J. W., Colwick, R. F., and Threadgill, E. D.
United States Department of Agriculture, Agricultural Research Service, State College, Mississippi.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 366-372, March-April, 1972. 8 fig, 2 tab, 24 ref.

Descriptors: *Environment, *Computer models, *Plant growth, Plant-Soil-Water-relationships, Model studies, Soil moisture, Climatic data, Precipitation (atmospheric), Environmental effects.

This study was designed to develop an environment model for crop production or other biological systems to provide inputs of daily rainfall, temperature, evaporation, and soil moisture variations with depth. The weather model was run on the computer and 10 years of simulated data were shown to compare very closely with observed data for State College. The soil moisture model produced results that fell within 10 percent of the observed data for at least 43 days. The models developed in this paper can be used to provide basic environmental variables for use in crop production simulations for studying complete systems at various locations. The methods of simulation developed show promise for studying and projecting environmental factors.
(See 72-73:06B-002)

72-73:02A-007
DEVELOPING SIMULATION MODELS,
James, W.
McMaster University, Department of Civil Engineering and Engineering Mechanics, Hamilton, Ontario, Canada.
Water Resources Research, Vol. 8, No. 6, p 1590-1592, December, 1972. 3 fig, 1 ref.

Descriptors: *Mathematical models, *Computer models, *Systems analysis, Model studies, Simulation analysis, Operations research, Synthetic hydrology.

Scheduling.

Simulation models are commonly resolved in time and space beyond the integrity of available field observations. Input data are fudged accordingly, and, ultimately, expensive simulation models coexist with inadequate data bases. Such manipulation is necessary in sensitivity analysis, but a compromise between data collection and model extrapolation must be found. The rationale for the systematic development of a simulation model and the concomitant data collection program is presented in this paper and should be useful for managing difficult simulation studies.

72-73:02A-008
ROLE OF MODELS IN GROUNDWATER MANAGEMENT,
Weber, E. M., and Hassan, A. A.
California Department of Water Resources, Sacramento.
Water Resources Bulletin, Vol. 8, No. 1, p 198-206, February, 1972. 3 fig, 1 tab.
(See 72-73:02F-065)

Descriptors: *Water management (applied), *Surface-groundwater relationships, *Water resources development, *Computer models, Mathematical models, Groundwater resources, Water utilization, Groundwater potential, Aquifer management, Groundwater, Surface waters.

To integrate operation of ground and surface water supplies into their management plans, decision-makers must be able to predict the effects of various alternative modes of operation and meteorological conditions on the groundwater basin. Many types of models have been used for simulating the behavior of groundwater basins under these changes. Analog simulators, analog computers, and digital computers have been employed for model development. To achieve plausible models, detailed hydraulic and hydrologic characteristics are required, such as data on transmissivity, storage, and net deep percolation. These data are used in the equations that form the model. Water quality, which cannot be separated from quantity, deserves equal consideration. Recently, considerable efforts have been made to develop water quality prediction tools through the use of modeling techniques.

72-73:02A-009
VOLUME BALANCE METHOD FOR COMPUTING INFILTRATION RATES IN SURFACE IRRIGATION,
Lal, R., and Pandya, A. C.
Orissa University of Agriculture and Technology, Bhubaneswar, India.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, p 69-72, January-February, 1972. 4 fig, 2 tab, 7 ref.
(See 72-73:04A-021)

72-73:02A-010
GROUNDWATER MANAGEMENT
Peters, H. J.
California Department of Water Resources, Division of Resources Development, Sacramento.
Water Resources Bulletin, Vol. 8, No. 1, p 188-197, February 1972. 1 fig.
(See 72-73:02F-067)

Descriptors: *Water management (applied), *Surface-groundwater relationships,

*Groundwater resources, Groundwater potential, Water utilization, Aquifer management, Base flow, Groundwater, Surface waters.

Groundwater management concepts have changed over the years, with today's concept a comprehensive integrated use of the four groundwater resources with surface water resources to provide the most efficient water service for an area in terms of quantity, quality, and cost. Complete geologic and hydrologic understanding provides a base for formulation of plans which can utilize the techniques of artificial recharge, control of sea water intrusion, and variation of pumping patterns while protecting the resources through proper well construction and abandohment, placement of sanitary landfills, and liquid waste disposal. Plan formulation involves varying recharge and extraction amounts while maintaining the total of pumped groundwater and developed surface water equal to the projected demand. Physical limitations of the system must be recognized to assure reality of the plans. Legal constraints should not be placed on the plan formulation process. A present worth or other technique is used to provide an economic comparison among plans. Implementation will entail development of legal and organizational structure, with the most difficult problems relating to the management organization in terms of boundaries and powers.

Section II

WATER CYCLE

PRECIPITATION (Group 02B)

72-73:02B-001
HUMIDITY EFFECTS ON YIELD AND WATER RELATIONS OF NINE CROPS,
Hoffman, G. J.
United States Salinity Laboratory, Riverside, California.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 1, p 164-167, January-February, 1973. 2 fig, 3 tab, 12 ref.

Descriptors: *Humidity, *Crop response, Mist, Moisture, Precipitation (atmospheric), Water vapor, Yielu equations, Water utilization.

The purpose of this paper is to summarize the effect humidity can have on the growth, yield, and water relations of nine crops grown under essentially the same controlled environmental conditions. Having essentially the same environment makes comparisons among crops possible. The data have been taken from various experiments conducted at the U. S. Salinity Laboratory to establish the interaction between atmospheric relative humidity and the salt tolerance of the crop. All the data reported here are from the nonsaline treatments. The results are therefore independent of salinity.

Section III

WATER CYCLE

SNOW, ICE, AND FROST (Group 02C)

72-73:02C-001
SPRING DISCHARGE OF AN ARCTIC RIVER DETERMINED FROM SALINITY MEASUREMENTS BENEATH SEA ICE,
Walker, H. J.
Louisiana State University, Baton Rouge, Coastal Studies Institute.
Water Resources Research, Vol. 9, No. 2, p 474-480, April 1973. 4 fig, 3 tab, 15 ref.

Descriptors: *Discharge measurement, *Streamflow, *Alaska, *Ice breakup, *Sea ice, Mixing, Salinity, Stream gages, Discharge (Water), Permafrost, Arctic.
Identifiers: *Colville River (Alaska).

Salinity measurements under sea ice seaward of the Colville delta in Alaska made possible the calculation of the river's discharge during breakup in 1971. Between May 27 and June 15 the discharge was 5.70 billion cu m, which is about 58% of the total for 1971. The entire drainage basin of the Colville River is confined to the zone of continuous permafrost. In winter both surface water and groundwater freeze, and the river ceases to flow. This cessation of flow allows seawater to occupy completely the delta front and to replace river water in the lower reaches of the river. After flushing the saltwater from the river channels, the floodwater intrudes between sea ice and seawater as it flows into the ocean.

Section IV

WATER CYCLE

EVAPORATION AND TRANSPIRATION (Group 02D)

72-73:02D-001
MODEL FOR PREDICTING EVAPORATION FROM A ROW CROP WITH INCOMPLETE COVER,
Ritchie, J. T.
Agricultural Research Service, Temple, Texas, Blackland Conservation Research Center.
Water Resources Research, Vol. 8, No. 5, p 1204-1213, October 1972. 5 fig, 2 tab, 23 ref.

Descriptors: *Evapotranspiration, *Evaporation, *Transpiration, *Sorghum, Lysimeters, Water balance, *Texas, Consumptive use, Humidity, Winds, Model studies, Mathematical models, Temperature.

A model is presented for calculating the daily evaporation rate from a crop surface. It applies to a row crop canopy situation in which the soil water supply to the plant roots is not limited and the crop has not come into an advanced stage of maturation of senescence. The crop evaporation rate is calculated by adding the soil surface and plant surface components (each of these requiring daily numbers for the leaf area index), the potential evaporation, the rainfall, and the net radiation above the canopy. The evaporation from the soil surface (Es) is calculated in two stages: (1) the constant rate stage in which Es is limited only by the supply of energy to the surface and (2) the falling rate stage in which water movement to the evaporating sites near the surface is controlled by the hydraulic properties of the soil. The evaporation from the plant surfaces (Ep) is predicted by using an empirical relation based on local data, which shows how Ep is related to the leaf area index. The model was used to obtain the total evaporation rate E equals Es plus Ep of a developing grain sorghum canopy in central Texas. The results agreed well with values measured directly with a weighing lysimeter.

72-73:02D-002
EVAPOTRANSPIRATION FROM A GREASEWOOD-CHEATGRASS COMMUNITY,
Harr, R. D., and Price, K. R.
Battelle-Pacific Northwest Laboratories, Richland, Washington, Ecosystems Department.
Water Resources Research, Vol. 8, No. 5, p 1199-1203, October 1972. 3 fig, 2 tab, 12 ref.

Descriptors: *Evapotranspiration, *Phreatophytes, *Water loss, *Drawdown, *Semiarid climates, Transpiration, Soil moisture, Groundwater, Arid lands, Water level fluctuations, Water balance, Climates, Pacific Northwest U.S.
Identifiers: Greasewood, Cheatgrass.

Groundwater elevation, soil moisture, and precipitation were monitored to evaluate the components of water loss from two greasewood-cheatgrass communities in south central Washington. Annual evapotranspiration was 21-25 cm, 18-31% of which was the transpiration of groundwater. The greatest loss from the system was the evapotranspiration of stored soil moisture, but this moisture was unavailable to greasewood. Water use is a function of depth of water up to 2.3 meters, but a more complicated mechanism operates at depths of up to

13 meters. Shrub height, canopy coverage, and total leaf surface area are inversely related to depth of water, and the rate of water use is in turn directly related to these features.

72-73:02D-003
EFFECT OF USING AVERAGED DATA ON THE COMPUTED EVAPORATION,
JOBSON, H. E.
Geological Survey, Fort Collins, Colorado.
Water Resources Research, Vol. 8, No. 2, p 513-518, April 1972. 1 fig, 10 ref.

Descriptors: *Evaporation, *Data processing, *Water loss, Equations, Mass transfer, Humidity, Winds, Statistics, Meteorological data, Oklahoma.
Identifiers: *Lake Hefner (Oklahoma).

Because it is seldom necessary to determine the total evaporation from a body of water for short periods of time, meteorologic data that have been averaged over long intervals of time and the semiempirical mass transfer equation are often used to determine the total evapoartion. The effect of averaging wind speeds and temperatures on the computed evaporation is discussed. Data collected during a 15-month interval at Lake Hefner near Oklahoma City, Oklahoma, were analyzed. Each set of data represents the average meteorologic conditions during a 30-minute time interval. From these data the effect of averaging for periods of 3 hours, 1 day, and 1 month was determined. The value of the coefficient in the semiempirical mass transfer formula is independent of the averaging time when this time is less than 1 day in length. The frequency distribution of the averaging error was determined for each averaging period. An averaging error larger than plus or minus 5% occurred about 3% of the time for 3-hour averages and about 20% of the time for daily averages. Averaging periods should be shorter than 1 month in situations similar to those at Lake Hefner.

72-73:02D-004
ERRORS IN OUTPUT OF HYDROLOGIC MODELS DUE TO ERRORS IN INPUT POTENTIAL EVAPOTRANSPIRATION,
Parmele, L. H.
Agricultural Research Service, University Park, Pennsylvania.
Water Resources Research, Vol. 8, No. 2, p 348-359, April 1972. 10 fig, 1 tab, 12 ref.

Descriptors: *Mathematical models, *Evapotranspiration, *Water balance, *Simulation analysis, Synthetic hydrology, Systems analysis, Rainfall-runoff relationships.
Identifiers: Error analysis (Model studies), Stanford Watershed Model.

To give some perspective to the importance of accurate evapotranspiration (ET) input data to hydrologic models, computed output from three hydrologic models was considered as the true watershed response. Variations in the form of random fluctuations and fixed biases were introduced into the potential evapotranspiration (Pet) input data of the test models. By leaving the other inputs and parameters unchanged, the effect of evapotranspiration on streamflow under the regulation of the other components in the model is shown. A constant bias of 20% in the Pet input data has a cumulative effect and results in considerable error in the computed hydrograph peaks and recession characteristics, whereas the influence of the random error on estimated streamflow was generally not measurable for the watersheds and models studied.

72-73:02D-005
SOIL-MOISTURE EFFECTS OF CONVERSION OF SAGEBRUSH COVER TO BUNCHGRASS COVER,
Shown, L. M., Lusby, G. C., and Branson, F. A.
Geological Survey, Lakewood, Colorado.
Water Resources Bulletin, Vol. 8, No. 6, p 1265-1272, December 1972. 3 fig, 1 tab, 8 ref.

Descriptors: *Evapotranspiration, *Grasses, *Sagebrush, *Soil water, *Colorado, *Evapotranspiration control, Soil moisture, Consumptive use, Sediment yield, Runoff, Vegetation effects, Water yield improvement, Water balance.

Precipitation, soil moisture, runoff, and vegetation were measured on two, 5- to 10-acre, big sagebrush watersheds and two, equally small, beardless bluebunch wheatgrass watersheds that were converted from big sagebrush in 1967. The watersheds are located near Wolcott, Colorado, at an elevation of 7,200 feet, and are mantled with 2 to 3 feet of silty clay soils. Annual precipitation was about 13.5 inches; about 9 inches occurred as rain or snow from April through October and about 4.5 inches accumulated as a snowpack from November through March. Evapotranspiration was about 2 inches greater in 1968 and 1 inch greater in 1969 from the sagebrush watersheds than from the grass watersheds. With a mature stand of grass in 1970 and 1971 the differencesin evapotranspiration were within the range of differences measured during the 3-year calibration period when all four watersheds were sagebrush. Water use was similar in the top 1 foot of soil but slightly more water was used by the grass in the 1- to 2-foot zone and more water was being used by the sagebrush below 2 feet. Soil-water potential data indicated that only the big sagebrush used a small amount of water from the fractured shale at depths below 40 inches. Sagebrush used more water in August and September than the grass.

72-73:02D-006
PEAK WATER REQUIREMENTS OF CROPS IN SOUTHERN IDAHO,
Wright, J. L., and Jensen, M. E.
Agricultural Research Service, Kimberly, Idaho, Snake River Research Center.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR2, p 193-201, June 1972. 4 fig, 8 ref.

Descriptors: *Evapotranspiration, *Climatic data, *Lysimeters, *Estimating equations, *Alfalfa, Irrigation practices, Frequency analysis, Winds, Arid lands, Micrometeorology, Crop response, Advection, *Idaho.
Identifiers: *Potential evapotranspiration, *Crop roughness.

Because of increasing water costs, the nature of many new sprinkler systems and because many areas like southern Idaho produce high-value crops that are extremely sensitive to moisture stress, capacities of new irrigation systems must be designed to closer tolerances. Two years of lysimeter measurements of evapotranspiration (ET) and the associated energy balance components were used to develop and verify procedures for estimating ET from meteorological data. Peak water use requirements for well-watered alfafa were determined for southern Idaho from frequency distributions of mean ET rates for 1-day, 3-day, 7-day, 15-day, and 30-day averaging periods. The daily ET computed showed large daily variations and demonstrated the need for frequency analysis and precise engineering planning for such arid regions. For the period of May through August, the peak single-day rate exceeded 0.4 in/day (10 mm). The peak 30-day period was from July 11 through August 10. As such information becomes available, it increases the need for yield estimates and economic return relationships of crops when managed at the various probability levels of peak ET rate.

72-73:02D-007
CENTRAL CALIFORNIA EVAPOTRANSPIRATION FREQUENCIES,
Pruitt, W. O., von Oettingen, S., Morgan, D. L.
California University, Davis, Department of Water Science and Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil
Engineers, Vol. 98, No. IR2, Paper 8941, p 177-184, June 1972. 2 fig, 9 ref.

Descriptors: *Evapotranspiration, *Frequency analysis, *Irrigation design, Variability, Statistics, Statistical methods, Probability, Climatology, Lysimeters, Soil-water-plant relationships, *California.
Identifiers: *Davis (California).

Frequency distribution patterns of daily evapotranspiration are presented for an irrigated grass cover grown in a highly sensitive weighing lysimeter at Davis, California, over a 10-year period. In response to climate variation, patterns ranged from highly skewed ones in winter to very close to normal distributions in midsummer. The importance of basing irrigation-system design on a careful analysis of probably variation of evapotranspiration rather than on long-term mean monthly data was dramatically illustrated. Even for crop and soil conditions requiring very infrequent irrigations, a system design must be some 15% higher than the 10-year monthly mean of 0.26 in. per day for June or July. In order to cover 99% of the cases under a crop-soil combination with only 1 in. of readily available moisture, the peak design rate would need to be 0.36 in. per day.

72-73:02D-008
COASTAL CALIFORNIA EVAPOTRANSPIRATION FREQUENCIES,
Nixon, P. R., Lawless, G. P., and Richardson, G. V.
Agricultural Research Service, Weslo, Texas, Soil and Water Conservation
Research Division; Agricultural Research Service, Beltsville, Maryland; and
Agricultural Research Service, Fort Collins, Colorado.
Journal of the Irrigation and Drainage Division, American Society of Civil
Engineers, Vol. 98, No. IR2, p 185-191, June 1972. 3 fig, 3 ref.

Descriptors: *Evapotranspiration, *Lysimeters, *Frequency analysis, *Coasts, *Valleys, Topography, Crops, Advection, Climatic data, *California, Winds, Growth stages, Grasses, Temperature.
Identifiers: *Crop roughness.

Year-round mild temperatures moving through gradual gradations characterize the climate of the coastal valleys of central California more than do clearly defined seasons. Because of advection cooling, fog and clouds along the Pacific Coast, the climate of these coastal valleys is influenced to some degree by maritime conditions. Examples of these influences are presented with data collected in a coastal valley 8 miles (13 km) from the ocean near Lompoc, California. The data are from 1 cu m hydraulical-weighing lysimeters containing irrigated perennial rye grass as an evapotranspiration (ET) reference crop. Because of the inaccuracy of ET prediction equations all climatic data were ignored. Monthly frequency distributions of daily ET and frequency distributions of 1-day through 30-day mean ET summer rates are presented. Although it would be very desirable to have more than the 2-1/4 yr of data that were available, it was felt that the frequency based on these data should consider that distance from the ocean has an important effect on ET rates in coastal valleys. Crop roughness and stage of growth are also influencing factors as well as ocean breezes and topography. Peak ET rates from field crops in this coastal valley can be 15-20% greater than rates of the aerodynamically smooth rye grass.

72-73:02D-009
MAXIMUM POTENTIAL EVAPOTRANSPIRATION FREQUENCY-EAST CENTRAL U. S.,
McGuinness, J. L., and Parmele, L. H.
Agricultural Research Service, Coshocton, Ohio, North Appalachian Experimental Watershed.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR2, Paper 8943, p 207-214, June 1972. 3 fig, 3 tab, 11 ref, append.

Descriptors: *Evapotranspiration, *Statistics, *Distribution patterns, *Variability, Probability, Irrigation, Planning, Lysimeters, Frequency analysis.

In the east-central United States maximum 1-day, 7-day, 15-day, and monthly values of evapotranspiration as measured by a lysimeter, and potential evapotranspiration as estimated by a computed lake evaporation are log-normally distributed. Equations were developed to estimate the two parameters of this distribution for any duration from 1 day to 1 month during the April to November season. A generalization of the data is made to a broad area of the east-central United States.

72-73:02D-010
FREQUENCY OF POTENTIAL EVAPOTRANSPIRATION RATES IN CENTRAL GREAT PLAINS,
Rosenberg, N. J.
Nebraska University, Lincoln, Department of Horticulture and Forestry.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR2, p 203-206, June 1972. 2 fig, 2 ref.

Descriptors: *Evapotranspiration, *Lysimeters, *Soil moisture, *Advection, *Great Plains, Crop response, Soybeans, Alfalfa, Nebraska, Agronomic crops, Irrigation efficiency.
Identifiers: *Potential evapotranspiration, *Soil water potential

As part of a study designed to improve crop water use efficiency, daily water use (ET) rates have been measured with precision lysimeters in an irrigated field in eastern Nebraska. Irrigation water was supplied whenever tensiometers and neutron probe access tubes indicated soil water potentials approaching 1 bar in the top 90 cm of soil. Daily ratios of evapotranspiration to net radiation were often greater than 1 for alfalfa and soybeans and therefore indicate strong advection in the region. Maximum ET for both crops has been approximately 12 mm per day. Seasonal frequency distributions of daily ET by a well-watered soybean crop are presented as an aid to irrigation design in the eastern Great Plains region. July is the greatest water use month because full canopy cover has been achieved and advection is high.

72-73:02D-011
WATER DEFICITS-IRRIGATION DESIGN AND PROGRAMMING,
Hagan, R. M., and Stewart, J. I.
California University, Davis.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR2, p 215-237, June, 1972. 2 fig, 2 tab, 124 ref.
(See 72-73:03F-010)

72-73:02D-012
SIMULATION OF SALT CEDAR EVAPOTRANSPIRATION,
Hughes, W. C.
Colorado University, Denver.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR4, Paper 9415, p 533-542, December, 1972. 6 fig, 6 ref, 3 append.

Descriptors: *Evapotranspiration, *Tamarisk, *Winds, Phreatophytes, Equations, Albedo, Stomata, Water loss.
Identifiers: *Roughness (Aerodynamic), *Penman equation.

The use of the Penman equation, as modified by Van Bavel and Monteith, for simulating evapotranspiration from dry plant surfaces requires knowledge of the surface albedo, surface roughness height and stomatal resistance. These variables were determined for salt cedar using measured values of salt cedar evapotranspiration. The equation was insensitive to variations in albedo so that values normally ascribed to vegetated surfaces could be used. The surface roughness height for salt cedar, 305 cm to 396 cm in height, was found to be 37 cm. The relative insensitivity of the equation to small variations in surface roughness height allowed for deviations of 10 cm to 15 cm without appreciable error. Stomatal resistance was varied seasonally from 0.3 sec per cm to over 5 sec per cm and was indirectly related to temperature and directly related to wind speed. Stomatal resistance was related to water depth only during seasons when the plants were inactive

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72-73:02D-013
NITROGEN FERTILIZATION AND CLIPPING EFFECTS ON GREEN NEEDLEGRASS (STIPA VIRIDULA TRIN.): II EVAPOTRANSPIRATION, WATER USE EFFICIENCY, AND NITROGEN RECOVERY.
White, L. M., and Brown, J. H.
Montana State University, Bozeman, Department of Agronomy.
Agronomy Journal, Vol. 64, No. 4, p 487-490, July-August 1972. 3 fig, 4 tab, 17 ref.

Descriptors: *Forage grasses, *Fertilizers, *Evapotranspiration, *Water utilization, *Plant growth regulators, Efficiencies, Consumptive use, Soil-water-plant relationships, Distribution patterns, Soil water, Nitrate, Nitrogen compounds, Nitrogen, Soil chemical properties, Limiting factors, Great Plains, Semiarid climates, Crop production, Grasslands, Dry farming, Moisture stress, Wilting.
Identifiers: *Clipping, *Green Needlegrass, *Nitrogen recovery.

Soil water and nitrogen (N) are the major factors limiting forage production in the semiarid Great Plains grasslands. Effects of N fertilization and clipping of dryland green needlegrass upon evapotranspiration (ET), water-use efficiency (WUE) and N fertilizer recovery are reported. N was broadcast at 0.70 and 140 kg of N/ha in November 1968; Green needlegrass (Stipa viridula Trin.) was either left unclipped or clipped to a 5-cm height five times during 1969 at 21-day intervals. Needlegrass showed visual signs of water stress when water was deficient in the surface 30 cm of soil On unclipped plots, 80 per cent of the ET was from this depth. WUE of unclipped grass increased during May and June and decreased during July, but that of clipped plants decreased from May through July. N fertilization increased and clipping decreased WUE. Average N recoveries with higher application rates were 22 percent for the first year and 8 per cent for the second. N recovery was highest with 70 kg of N/ha and frequent clipping. Low N recovery was not due to leaching. At the end of the first crop season, 7 per cent of the 70 kg N/ha applied and 17 per cent of the 140 kg of N/ha applied the previous year remained in the soil as nitrate-N. Soil water in the 0 to 30-cm soil depth controlled grass wilting.

72-73:02D-014
EVAPORATION OF WATER FROM SAND, 1: EXPERIMENTAL SET-UP AND CLIMATIC INFLUENCES,
Hellwig, D. H. R.
National Institute for Water Research, Windhoek (South-West Africa), Regional Laboratory.
Journal of Hydrology, Vol. 18, No. 2, p 93-108, February 1973. 8 fig, 9 tab, 7 ref.

Descriptors: *Evaporation, *Alluvial channels, *Alluvial aquifers, *Evaporimeters, *Climates, Water loss, Humidity, Soil water, Sands, Underflow, Surface-groundwater relationships, Water temperature, Diurnal.

The influence of climate on rate of evaporation from sand was studied in South African alluvial channels. Solar radiation is the principal factor affecting evaporation. Air temperature affects evaporation only indirectly. Both rate of evaporation and air temperature result from the energy supplied by solar radiation. The effect of the relative humidity is far outweighed by other climatic factors. At times wind had a marked effect on evaporation. Under the conditions prevailing at the test site, climatic factors complemented each other in changes of evaporation. The temperature of the water at the water table did not appear to be an imporatnt factor; it influenced evaporation indirectly by conveying radiation energy and was in itself affected by evaporation.

72-73:02D-015
EVAPORATION OF WATER FROM SAND, 2: DIURNAL VARIATIONS,
Hellwig, D. H. R.
National Institute for Water Research, Windhoek (South-West Africa), Regional Laboratory,
Journal of Hydrology, Vol. 18, No. 2, p 109-118, February 1973. 5 fig, 2 tab, 17 ref.

Descriptors: *Evaporation, *Alluvial channels, *Alluvial aquifers, *Evaporimeters, *Climates, Water loss, Humidity, Soil water, Sands, Underflow, Surface-groundwater relationships, Water temperature, Diurnal.

In evaporation tests with moist sand, an evaporation peak was observed just before sunrise. Neither the vapor pressure gradient between water table and atmosphere, nor the fact that the vapor pressure difference between water table and atmosphere exceeded the vapor pressure deficit of the air during the night, could fully explain this phenomenon. The temperature difference between that of the water table and that of the atmosphere correlated well with evaporation during the night and seemed to be a determining factor during that period.

72-73:02D-016
AN AERODYNAMIC FORMULA TO COMPUTE EVAPORATION FROM OPEN WATER SURFACES,
Lakshman, G.
Saskatchewan Research Council, Saskatoon.

Journal of Hydrology, Vol. 15, No. 3, p 209-225, March 1972. 17 fig, 1 tab, 15 ref, 2 append.

Descriptors: *Evaporation, *Winds, *Reservoir evaporation, Humidity, Climatology, Meteorology, Mass transfer, Advection, Temperature, Vapor pressure, Canada.
Identifiers: Aerodynamics.

A formula to compute evaporation from open water surfaces is derived using wind profile characteristics. The mass transfer coefficient is given as a function of the shape and size of the water body in addition to the turbulent boundary layer parameters. The formula has been applied successfully to lakes and reservoirs of areas ranging from a fraction of an acre to thousands of acres. It is also given in a simplified form for application to cases where the wind profile measurements are not made.

72-73:02D-017
DRYLAND EVAPORATIVE FLUX IN A SUBHUMID CLIMATE: IV. RELATION TO PLANT WATER STATUS,
Ritchie, J. T., and Jordan, W. R.
Agricultural Research Service, Temple, Texas, Soil and Water Conservation Research Division,
Agronomy Journal, Vol. 64, No. 2, p 173-178, 1972. Illus.

Descriptors: Climates, Evapotranspiration, Moisture, Soils, Transpiration, Water balance, *Subhumid climates.
Identifiers: Dryland, *Evaporative flux, *Leaf, Plants, Sorghum-Bicolor-M, *Plant-water status.

Seasonal trends in relative water content (RWC) of grain sorghum (Sorghum bicolor (L.) Moench) were measured concurrently with evaporation rates during a prolonged drying cycle in 1969. When the available soil water supply was depleted beyond a critical threshold, called the lower limit for potential evaporation (LLEO), daily evaporation rates began to decline substantially below the level of energy available for evaporation. Before the LLEO threshold was reached, midday leaf RWC values were approximately 0.90. Afterwards, these values declined in proportion to measured decreases in daily evaporation. Early morning RWC values did not decrease significantly until 8 days after evaporation began to decline. Leaf stomatal response to soil water deficit was evident when daylight leaf diffusion resistances changed from 2 sec/cm before the LLEO threshold to about 25 sec/cm 10 days after the threshold was reached. Plant water status can be used in conjunction with measured changes in soil water content to define the amount of soil water extractable by plant roots for a particular crop, soil, and climate between the maximum water-holding capacity of the soil and the LLEO threshold. These critical soil water parameters can be applied to predicting evaporation in 2 stages: a freely evaporating stage when evaporation is limited by the amount of energy available for evaporation; and a falling rate stage when evaporation declines below the potential rate. An equation is proposed for predicting evaporation in the falling stage as an exponentially decreasing function of time after the LLEO threshold is reached.

72-73:02D-018
DRYLAND EVAPORATIVE FLUX IN A SUBHUMID CLIMATE: III. SOIL WATER INFLUENCE,
Ritchie, J. T., Burnett, E., and Henderson, R. C.
Agricultural Research Service, Temple, Texas, Soil and Water Conservation Research Division.

Agronomy Journal, Vol. 64, No. 2, p 168-173, 1972. Illus.

Descriptors: Climates, Evapotranspiration, Evaporation, Flow, *Soil water, Transpiration, Wilting.
Identifiers: Dryland, *Evaporative flux, *Gossypium-D-Sp, Rooting, *Sorghum-Bicolor-M, Unsaturated.

The relationship between evaporative rates of field-grown cotton (Gossypium Sp.) and grain sorghum (Sorghum bicolor (L.) Moench) and the soil water status for use in predicting evaporation on watersheds was studied. Soil water content and soil water matric potential of Houston Black clay were measured throughout complete growing seasons for cotton and grain sorghum concurrently with measurements of the daily evaporation rate. Evaporation rates were independent of the soil water status until soil water was depleted beyond a threshold value. This threshold, termed the lower limit for potential evaporation (LLEO), was reached when approximately 18.2 cm of water had been removed from a soil profile initially wet. Another 6.5 cm of soil water was extracted at a decreasing rate before exaporation practically stopped. Evaporation rates after the LLEO threshold was reached were practically independent of the energy available for evaporation and depended on the rooting distribution and the water movement to the roots. An analysis of the soil water transmission characteristics after the threshold LLEO was reached showed that practically all the water extracted by plant roots was moving from the volume of soil immediately surrounding the roots. The need for growing crops with deep, dense root systems in dryland for maximum utilization of stored soil water is indicated.

72-73:02D-019
EVAPOTRANSPIRATION FROM SOYBEAN AND SORGHUM FIELDS,
Brun, Lynn J., Kanemasu, Edward T., and Powers, William L.
Kansas State University, Manhattan, Department of Agronomy.
Agronomy Journal 64(2): 145-148, 1972. Illus.

Descriptors: *Evapotranspiration, Heat, Indexing, Soils, Transpiration.
Identifiers: Flux, Leaf, *Sorghum-M, *Soybean-D, Stomatal resistance.

The evapotranspiration model, presented by Monteith (1965) and later tested by Black et al. (1970) on a loosely structured snap bean (Phaseolus vulgaris) canopy, was used to separate soil evaporation and transpiration on soybean (Glycine max (L.) Calland) and sorghum (Sorghum bicolor (L.) 'Pioneer No 846') canopies during the growing season. Soil evaporation was estimated as the net radiation below the crop canopy minus the soil heat flux. Stomatal resistance was determined with the diffusion porometer (Kanemasu et al. 1969). Potential evapotranspiration, soil evaporation, and transpiration rates were determined on an hourly basis. The sum of transpiration and soil evaporation was compared to the lysimetric estimates of evapotranspiration. The model and the lysimeters were in agreement, except under conditions of high atmospheric demand when the model underestimated actual evapotranspiration. The model showed the proportion of water lost as transpiration was closely correlated to leaf area index (LAI) with transpiration at approximately 50% of the total evapotranspiration at a LAI of 2 and as much as 95% at a LAI of 4.

72-73:02D-020
AN IRRIGATION SCHEDULING MODEL WHICH INCORPORATES RAINFALL PREDICTIONS,
Rochester, E. W., and Busch, C. D.

Auburn University, Agricultural Experiment Station, Agricultural Engineering Department, Auburn, Alabama.
Water Resources Bulletin, Vol. 8, No. 3, p 608-613, June, 1972. 5 fig, 5 ref.

Descriptors: *Irrigation, *Scheduling, *Irrigation practices, Supplemental irrigation, Soil moisture, Evapotranspiration, Consumptive use, Agricultural engineering, Mathematical models, Computer models.
Identifiers: Irrigation scheduling.

In humid areas appreciable amounts of rainfall complicate irrigation scheduling. This rainfall tends to give supplemental water application a low priority. Irrigation may be delayed until there is not enough time to cover the crop area before some drought damage occurs. To improve the management of irrigation systems, a scheduling model has been developed. The model's water application decisions incorporate climatological records, soil-plant data, current pan evaporation and rainfall, the number of fields to be irrigated, and 5-day weather forecasts. The model updates the soil moisture conditions, predicts impending water depletion, and if supplemental water is needed both the field priority and amounts to be applied is indicated for each of the next 5 days. Errors introduced through the use of forecasts and long-term pan evaporation records have been slight because of the tri-weekly updating. Also natural rains which restore the root zone to maximum water holding capacity prevent long-term bias.

72-73:02D-021
SOME EVIDENCE OF STOMATAL RESTRICTION OF EVAPORATION FROM WELL-WATERED PLANT CANOPIES,
Shepherd, W.
Commonwealth Scientific and Industrial Research Organization, Division of Atmospheric Physics, Aspendale, Victoria, Australia.
Water Resources Research, Vol. 8, No. 4, p 1092-1095, August, 1972. 2 tab, 4 fig, 10 ref.

Descriptors: *Evapotranspiration, *Stomata, *Water requirements, Soil-water-plant relationships, Consumptive use, Hydrologic cycle, Soil moisture, Moisture, Water conservation.

Various aspects of stomatal control of evaporation and their practical significance have been considered in a recent exchange of opinions in this journal. The present paper describes some considerable departures from potential evaporation rates observed under conditions of generous soil water supply. These departures occurred on days of high potential rates and represented reductions of up to about 20% from levels that might otherwise have been expected under the prevailing atmospheric conditions. However, the reductions represented only a few percent of the seasonal or annual evaporation. Accompanying symptoms of plant moisture stress are discussed.

72-73:02D-022
WATER REQUIREMENTS OF ROSTERED IRRIGATION SCHEMES,
Fitzgerald, P. D., and Arnold G. C.
Department of Agriculture, Ashburton, New Zealand.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR1, p 91-96, March, 1972. 1 fig, 3 tab, 4 ref.
(See 72-73:04A-025)

72-73:02D-023
DIURNAL SOIL-WATER EVAPORATION: TIME-DEPTH-FLUX PATTERNS,
Jackson, R. D., Kimball, B. A., Reginato, R. J., and Nakayama, F. S.
Agricultural Research Service, Phoenix, Arizona, Water Conservation Laboratory.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 505-509, July-August 1973. 8 fig, 6 ref.

Descriptors: *Evaporation, *Soil Water movement, Drying, Air-earth interfaces, Lysimeters, Evaporimeters.

Time-depth patterns of soil water flux in the 0- to 9-cm zone of a bare field soil are described for four 24-hour periods at 3, 7, 16, and 37 days after irrigation. On day 3, the flux at 0 cm (Evaporation) dominated the flux patterns for all depths. As the soil dried, this flux decreased and those at the greater depths gradually became dominant. On all 16 days of measurement, downward flux was observed below 1 to 3 cm during several hours between sunrise and early afternoon. Only one period of downward flux was observed for day 3, but 2 to 4 periods were noted for subsequent days. These patterns demonstrate the dynamic nature of soil water flux in the surface zone of a field soil subjected to diurnally varying environmental conditions.

72-73:02D-024
PREDICTION OF EVAPORATION FROM HOMOGENEOUS SOIL BASED ON THE FLOW EQUATION,
Gardner, H. R.
Agricultural Research Service, Fort Collins, Colorado.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 513-516, July-August 1973. 3 fig, 3 tab, 3 ref.

Descriptors: *Evaporation, *Soil water movement, *Water loss, Diffusivity, Air-earth interfaces, Equations, Soil moisture, Soil water.
Identifiers: Soil water evaporation.

Evaporation of water from columns packed with McGrew loamy sand was measured for three different sequences of six water additions and evaporation times totaling 60 days. These treatments were: (1) equal amounts of water added and equal times evaporated, (2) equal amounts applied and varied evaporation times, and (3) various amounts applied and equal evaporation times. The average times and amounts were the same in all treatments, and the total losses were approximately the same. A solution for the diffusivity equation for soils of finite depth was used to predict the cumulative water loss for all the treatments event by event and by an averaging technique. The predicted amounts were all within 6.5% of the total cumulative evaporation.

72-73:02D-025
DIURNAL SOIL-WATER EVAPORATION: CHLORIDE MOVEMENT AND ACCUMULATION NEAR THE SOIL SURFACE,
Nakayama, F. S., Jackson, R. D., Kimball, B. A., and Reginato, R. J.
Agricultural Research Service, Phoenix, Arizona, Water Conservation Laboratory.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 509-513, July-August 1973. 9 fig, 10 ref.

Descriptors: *Evaporation, *Chemical precipitation, *Soil water, Soil water movement, Water chemistry, Diurnal, Chlorides, Soil chemistry, Leaching, Mass transfer, Ion transport.

Movement and accumulation of chloride at shallow depths (0 to 9 cm) were studied in a bare soil following an irrigation. Chloride accumulation in the 0- to 0.5- and 0- to 1-cm depth increments followed a diurnal pattern but out-of-phase from the soil water content during the first few days after irrigation. The diurnal amplitude of chloride decreased with time as the soil progressively dried. At 1- to 2-cm and deeper depths, diurnal cycling of the chloride content was not measurable, whereas cycling in the water content was evident. Most of the total chloride accumulation at the shallowest depth occurred in the early stages of drying. However, chloride movement was detected as low as 4% volumetric water content or approximately 1,000 bars soil water potential.

72-73:02D-026
WATER VAPOR MOVEMENT THROUGH MULCHES UNDER FIELD CONDITIONS,
Kimball, B. A.
United States Water Conservation Laboratory, Phoenix, Arizona.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 813-818, November-December, 1973. 3 fig. 2 tab, 24 ref.

Descriptors: *Mulching, *Evaporation control, Soil conservation, Water conservation, Water loss, Water vapor.

The loss of water vapor through 0.5-, 1-, and 2-cm depths of water repellent mulches was measured under field conditions with lysimeters. Concurrent measurements were made of wind velocities, air vapor pressures, and temperatures at the soil-mulch interfaces. Mulches used included 0.5-, 1-, and 2-mm glass beads and 1-mm glass bead aggregates. By assuming that the relative humidity of the soil air at the soil-mulch interface was essentially 100%, effective diffusion coefficients for field conditions were calculated. The average effective diffusion coefficient for afternoon periods was 1.26 times greater than the molecular diffusion coefficient. An error analysis revealed that the value could have been as low as 0.90 or as high as 1.63, but these values would have been realized only if the effects of several possible systematic errors were completely additive. Little correlation was found between wind velocity and effective diffusion coefficient. However, the generally low range in wind velocities observed and the smoothing required for the reduction of the lysimeter data may have prevented detection of such a correlation.

72-73:02D-027
APPLICATION OF THE GRID SQUARE TECHNIQUE TO MAPPING OF EVAPOTRANSPIRATION,
Foyster, A. M.
Exeter University (England), Department of Geography.
Journal of Hydrology, Vol. 19, No. 3, p 205-226, July 1973. 14 fig, 30 ref.

Descriptors: *Mapping, *Evapotranspiration, Runoff, Precipitation (Atmospheric), *Computer programs, Water balance, *Data processing, Hydrologic data, *Climatic data, Networks, Meteorological data.

A method of producing potential evapotranspiration maps for a part of southwest England uses grid-based extrapolation. Penman's equation was chosen to estimate potential evapotranspiration because it uses readily available climatic data and it produces estimates that closely resemble evaporation pan or lysimeter readings. A computer-oriented technique in association with grid data provides the best solution. A grid approach not only simplifies the production of maps but also facilitates data storage, retrieval, and processing because each square is defined by a pair of Cartesian coordinates. The easy referencing quality of a grid also allows the processing of data from subgroups of squares. Data from topographic maps is used to assemble a physiographic data file for each grid square. This file is then used as a set of independent variables in multiple regression analysis in order to extrapolate the climatological data over a grid. In this way, a file of climatological data is set up for every grid square. Values of 2 theoretical meteorological parameters are derived for each square by substituting values of physiographic parameters and daily declination of the sun and the earth-sun radius vector, into Okanoue's equation. This formula gives values of maximum possible incident radiation and maximum possible sunshine hours. Penman's monthly potential evapotranspiration estimates are then calculated by applying Penman's formula to the climatic and meteorological information for each individual grid square.

72-73:02D-028
EVAPORATION OF WATER FROM SAND, 3: THE LOSS OF WATER INTO THE ATMOSPHERE FROM A SANDY RIVER BED UNDER ARID CLIMATIC CONDITIONS,
Hellwig, D. H. R.
National Institute for Water Research, Ausspannplatz, Windhoek, South West Africa.
Journal of Hydrology, Vol. 18, No. 3/4, p 305-316, March 1973. 2 fig, 5 tab, 17 ref.

Descriptors: *Evaporation, *Evapotranspiration, Consumptive use, Water loss, Phreatophytes, Arid Climates.

The Penman formula was applied to calculate evaporation and evapotranspiration losses under arid climatic conditions from a sandy river bed. Good agreement with measured results was obtained. The loss of water into the atmosphere from a river bed covering 8300 ha was estimated to be 76 million cubic meters per year. Evapotranspiration contributed 68% and permanently wet areas 19.5% to the total water loss. The rest evaporated from temporary wet areas. Substantial volumes of water can possibly be gained by the removal of phreatophytes.

72-73:02D-029
EVAPORATION OF WATER FROM SAND, 4: THE INFLUENCE OF THE DEPTH OF THE WATER-TABLE AND THE PARTICLE SIZE DISTRIBUTION OF THE SAND,
Hellwig, D. H. R.
National Institute for Water Research, Ausspannplatz, Windhoek, South West Africa.
Journal of Hydrology, Vol. 18, No. 3/4, p 317-327, March, 1973. 6 fig, 5 tab, 11 ref.

Descriptors: *Evaporation, *Consumptive use, Water loss, Arid climates, Water table, Depth, Groundwater.

Experiments were carried out to determine the influence of the depth of the water-table and the particle size of sand on evaporation of water from sand. Dropping the water-table in sand, with a mean diameter of 0.53 mm, below 60 cm will practically prevent evaporation losses. The coarseness of the sand does not effect evaporation if the water-table is kept at the sand surface. If the water-table is kept below the sand surface, evaporation decreases with the coarseness of the sand and with the depth of the water-table. Evaporation from an open water surface was 8% higher than from water-saturated sand, most probably due to higher energy storage in a body of water resulting in a greater temperature gradient between the evaporation surface of the water and the air during the night, as compared to a water-saturated sand.

72-73:02D-030
L'EVAPORATION D'UN BAC D'EAU LIBRE - SA SIGNIFICATION RESTREINTE,
Bultot, F., and Dupriez, G. L.
Section d'Hydrologie de l'Institut Royal Meteorologique, Uccle (Belgique).
Journal of Hydrology, Vol. 20, No. 1, p 83-95, September 1973. 2 fig, 2 tab, 9 ref.

Descriptors: *Solar radiation, *Evaporation, Evapotranspiration.

There is no simple relation nor even a strong correlation between daily evaporations measured by means of a water pan and potential evapotranspirations of neighboring natural surfaces. Generally, the evaporation of the pan is reduced in a certain proportion due to the fact that the incident global solar radiation penetrates partially into the water and because consequently a portion of the radiant energy flux is not caught by the surface. Nevertheless, during rainy periods and also under certain meteorological conditions, the evaporation of the pan is increased paradoxally as a result of a fast transfer of heat from underlying water layers towards the surface, by turbulent diffusion.

72-73:02D-031
A WEIGHING SYSTEM FOR LYSIMETERS,
Voisey, P. W., and Hobbs, E. H.
Agriculture Canada, Research Branch, Engineering Research Service, Ottawa, Ontario.
Canadian Agricultural Engineering, Vol. 14, No. 2, p 82-84, December 1972. 3 fig, 25 ref

Descriptors: *Lysimeters, *Weight, Evapotranspiration, Soil moisture, Soil water, Consumptive use, Soil-water-plant relationships.

A technique is described for weighing lysimeters using a strain gage load cell and an electronic indicating system. The nominal weight of the lysimeter is eliminated from the measurement by offsetting the indicator zero electrically using a weight. This increases the possible resolution and accuracy of measurement. In the example described, weight changes of ±22.7 kilogrammes in lysimeters weighing 180 kilogrammes with a resolution of 0.045 kilogrammes and accurate within 0.090 kilogrammes were measured. Weighing of 36 such lysimeters could be accomplished in 2 hours.

72-73:02D-032
CONSERVING WETLAND WATER BY SUPRESSING EVAPORATION,
Rutherford, R. J., and Byers, G. L.
New Hampshire University, Water Resources Center, Durham, New Hampshire.
Canadian Agricultural Engineering, Vol. 15, No. 1, p 9-11, June, 1973. 1 fig, 2 tab, 8 ref.

Descriptors: *Evaporation, *Evaporation Control, Water loss, Consumptive use, Evapotranspiration, Chemcontrol, monomolecular films, Thin films, Water conservation.

Evapotranspiration from the muck and peat bog of Jewell Pond in Stratham, New Hampshire, was 1.7 times as great as the evaporation from the open water surface during the summer of 1969. The wetland released 16.9 centimeters of water from storage during the same period. During the summer of 1970, an evaporation retardant was used to reduce open water evaporation. The objective of this management practice was to increase water yields and augment water supplied during dry months. The retardant successfully reduced evaporation by 47 percent. Additional water supplies obtained by the use of evaporation retardants could be used for domestic and commercial consumption.

72-73:02D-033
CROP COOLING WITH SPRINKLERS,
Hobbs, E. H.
Agriculture Canada, Research Branch, Research Station, Lethbridge, Alberta.
Canadian Agricultural Engineering, Vol. 15, No. 1, p 6-8, June, 1973. 3 fig, 1 tab, 15 ref.

Descriptors: *Temperature control, *Sprinkling, Coolants, Water, Temperature, Irrigation practices, Surface irrigation, Sprinkler irrigation, Climates.

Irrigated plots of potatoes and bush beans were sprinkled intermittently with water whenever the ambient air temperature exceeded 80 degrees Fahrenheit. Conventional but low-volume irrigation equipment was used to apply the cooling water at a net theoretical application rate of 0.026 inches per hour. Over a 3-year period and 88 applications this sprinkling rate effectively reduced plant canopy air temperature. The average temperature reduction was 6 Fahrenheit degrees but reductions as large as 16 Fahrenheit degrees occurred. The amount of cooling achieved was dependent upon the weather prevailing during cooling. Humidity exerted the greatest single influence, maximum air temperature was next in importance, and wind was less well related. The multiple regression equations indicate the amount of temperature reduction likely to be achieved with field-type sprinkler irrigation equipment.

72-73:02D-034
CALCULATION OF EVAPORATION FROM MEASUREMENTS OF SOIL WATER AND THE SOIL WATER CHARACTERISTIC,
Stammers, W. N., Igwe, O. C., and Whiteley, H. R.
Guelph University, School of Engineering, Guelph, Ontario, Canada.
Canadian Agricultural Engineering, Vol. 15, No. 1, p 2-5, June, 1973. 6 tab, 5 ref.

Descriptors: *Evaporation, *Soil surfaces, Evapotranspiration, Soil moisture, Soil water, Soil types, Mathematical models.

An approach based on the existence of a plane of zero soil-water flux is used to develop a model for calculating evaporation from soil-water measurement. The information required is a knowledge of soil water, capillary potential relationships for the soil considered, and soil-water content at the beginning and end of each time period of evaporation computation. This approach yields results that do not differ significantly from those obtained by assuming a fixed soil depth for calculations and ignoring soil-water seepage.

72-73:02D-035
A MINIATURE STRIP NET RADIOMETER,
Harper, L.A.
United States Department of Agriculture, Agricultural Research Service, Watkinsville, Georgia.
Agronomy Journal, Vol 64, No 3, P 403-405, May-June, 1972. 4 fig, 9 ref.

Descriptors: *Solar radiation, Energy, Evaporation, Hydrologic cycle.

An inexpensive miniature strip net radiometer was constructed for average net radiation measurement along a horizontal line in dense foliage such as short grasses or row crops. The sensing surface was 1.3 x 40 cm and was enclosed in a polyethlene shield for protection against wind and weather. The unit was calibrated relative to a temperature-compensated, net-exchange radiometer, and gave a linear response.

72-73:02D-036
INCREASE IN CONDUCTIVITY OF IRRIGATION WATER DURING SPRINKLING,
Robinson, F.E.
California University, Department of Water Science and Engineering, Davis.
Agronomy Journal, Vol. 65, No. 1, p 130, January-February, 1973. 3 ref.

Descriptors: *Salinity, Sprinkler irrigation, Evaporation, Irrigation practices, Irrigation engineering.

The test was conducted on a high evaporative demand July day to evaluate the possible harm that could result from concentration of salinity as water is sprinkled in an arid desert area. Catchment breakers (250 ml) were set at 19-m intervals across a 190- x 219-m alfalfa field that was sprinkled for 19.5 hours. Conductivity of the sprinkler water increased 21% on the field edge and 4.4% inside the field.

72-73:02D-037
QUANTATIVE SOIL MOISTURE USE IN CORN GROWN UNDER CONVENTIONAL AND NO-TILLAGE METHODS,
Hill, J.D. and Blevins, R.L.
National Weather Service, Lexington, Kentucky.
Agronomy Journal, Vol. 65, No. 5, p 945-949, November-December, 1973. 7 fig, 1 tab, 8 ref.

Descriptors: *Soil moisture, *Moisture stress, *Corn, Crop production, Crop response, Cultivation, Farm management, Mulching.

Experiments conducted at the University of Kentucky during 1969, 1970, and 1971 compared corn production under conventional and no-tillage systems. The presence of a killed-sod mulch in the no-tillage plots almost eliminated the loss of moisture by direct evaporation from the soil surface during the early growing period, but after a full crop canopy had developed, losses from both production methods were about equal. Water loss from the soil during the full-canopy period was compared with open pan evaporation to determine the rate of loss under varying levels of soil moisture deficiency. The average soil moisture deficiency during the period from about three weeks before to six weeks after silking was related to final grain yield, and a simple linear relationship indicated that each additional cm of water available to the plant increased yields by about 559 kg/ha.

72-73:02D-038

INFLUENCE OF SOIL WATER STATUS AND METEOROLOGICAL CONDITIONS ON EVAPORATION FROM A CORN CANOPY,

Ritchie, J. T.

United States Department of Agriculture, Agricultural Research Service, Temple, Texas.

Agronomy Journal, Vol. 65, No. 6, p 893-897, November-December, 1973. 3 fig, 21 ref.

Descriptors: *Evapotranspiration, *Corn, *Lysimeters, Irrigation design, Water utilization, Crop response, Yield equations.

This study was conducted to determine actual evaporation rates of corn as influenced by soil water status and potential evaporation rate. Actual evaporation rates were measured during the 1972 growing season with a weighing lysimeter. Evaporation rates were found to be practically independent of the soil water status for all existing conditions of potential evaporation. During the season more than 20 cm of soil water was removed from the 120-cm deep profile. Leaf diffusion resistance and leaf water potential measurements indicated that at least 80% of the extractable soil water was freely available to plant roots.

Section V

WATER CYCLE

STREAMFLOW AND RUNOFF (Group 02E)

72-73:02E-001
NOTE ON THE FINITE ELEMENT SOLUTION OF THE DIFFUSION-CONVECTION EQUATION,
Guymon, G. L.
Alaska University, College, Institute of Water Resources.
Water Resources Research, Vol. 8, No. 5, p 1357-1360, October 1972
1 fig, 5 ref.

Descriptors: *Finite element analysis, *Numerical analysis, *Diffusion, *Convection, Mathematical studies, Turbulence, Currents (Water), Unsteady flow, Non-uniform flow.

An improved formulation of the finite element procedure, based on a variational principle, yields superior results to a previous formulation of the finite element method. Numerical dispersion, introduced into the previous formulation by a transformation procedure that is unneccessary, is substantially reduced by the new procedure. The improved formulation of the problem yields a stable solution for a hypothetical stream mass transport problem.

72-73:02E-002
FLOW ROUTING MODELS FOR STREAM SYSTEM STUDIES,
Jennings, M. E., and Sauer, V. B.
Geological Survey, Washington, D. C., Water Resources Division.
Water Resources Bulletin, Vol. 8, No. 5, p 948-956, October 1972. 11 fig, 15 ref.

Descriptors: *Routing, *Frequency analysis, *Streamflow forecasting, Simulation analysis, Frequency curves, Regression analysis, Reservoir operation, Water management (Applied), Unsteady flow.

Studies to determine frequency characteristics of regulated streams at points within a stream system require the use of flow routing models. This study compares several different flow routing methods using data from six river reaches. Results indicate that approximate flow routing methods yield good flow estimates when compared with observed flows. The unit response method, recently introduced, performed as well as other approximate methods for all reaches studied and gave better results for reaches subject to power releases.

72-73:02E-003
BORDER IRRIGATION ADVANCE AND EPHEMERAL FLOOD WAVES,
Smith, R. E.
Agricultural Research Service, Tucson, Arizona, Southwest Watershed Research Center.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR2, p 289-307, June 1972. 13 fig, 16 ref.

Descriptors: *Mathematical models, *Floods, *Hydrology, *Irrigation, *Infiltration, Routing, Channels, Arroyos, Flood waves, Ephemeral streams.
Identifiers: *Kinematics, *Transmission loss.

A kinematic wave is a wave whose properties can be described by an equation of continuity and a stage-discharge relation, implying that momentum changes are negligible. A method is described of predicting advance rate, surface profiles and modifications with time to kinematic wave flow over an initially dry infiltrating plane. Point infiltration rate is considered to be a function of time since wetting. The model developed is shown to describe 2 common hydrological problems: border irrigation advance and attenuation in dry alluvial channels such as commonly occurs in the southwestern U.S. Numerical methods for solving the equations developed are described and illustrated. The partial differential equations for kinematic wave movement under time-varying space-varying lateral losses were reduced to 2 characteristic orginary differential equations and combined with a third equation for shock movement. Sensitivity for advance rate to the infiltration functions is shown. The model may be used to route floods through dry infiltrating channels.

72-73:02E-004
CHANGES IN WATER YIELD OF SMALL WATERSHEDS BY AGRICULTURAL PRACTICES,
Richardson, C. W.
United States Department of Agriculture, Agricultural Research Service, Riesel, Texas,
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 591-593, May-June, 1972. 7 fig, 5 ref.

Descriptors: *Hydrology, *Flow, Precipitation (atmospheric), Reservoir yield, Runoff, Surface waters, Watersheds (basins).

Agricultural practices can have a significant effect on on-site runoff from small watersheds. A simple statement that improved agricultural practices alter by a given percentage the runoff that would have occurred if the practices were not in effect is insufficient for water yield design purposes. The effect of conservation practices on water yield is highly dependent on the management level that is associated with the structural measures. Poor management practices on terraced areas may actually result in increases in water yield. The effect of conservation practices diminishes as watershed size becomes larger. On areas larger than about 300 acres, little effect of conservation practices have been noted.

72-73:02E-005
AN IRRIGATION SCHEDULING MODEL WHICH INCORPORATES RAINFALL PREDICTIONS,
Rochester, E. W., and Busch, C. D.
Auburn University, Auburn, Alabama.
Water Resources Bulletin, Vol. 8, No. 3, p 608-613, June, 1972. 5 fig, 5 ref.
(See 72-73:02D-020)

72-73:02E-006
INTERNATIONAL MANAGEMENT OF THE RIO GRANDE BASIN - THE UNITED STATES AND MEXICO,
Day, J. C.
Western Ontario University, Department of Geology, London, Canada.
Water Resources Bulletin, Vol. 8, No. 5, p 935-947, October, 1972. 3 fig, 18 ref.

Descriptors: *International waters, *Rio Grande River, *International Bound. and Water Comm., Water management (applied), United States, Mexico, Interstate rivers.
Identifiers: International water management.

Mexico and the United States forged a common program to manage water and related land on the Rio Grande. Actions of Rio Grande Commissions related to stream gaging, boundary definition, and multiple-purpose construction projects are among the more successful international water-management efforts in the world. Cost-sharing arrangements promoted rapid completing of international works. Joint action accomplished only part of expectations. International developments were competitive rather than complementary until basin water appropriation was virtually complete. Commissions were not employed to consider long-range competitive water needs, or regional water requirements, throughout the basin. International groundwater use coordination does not exist. International structures produce less than anticipated benefits. Hydroelectric generators are financial liabilities, irrigated acreage exceeds dependable streamflow, and soil salinization is experienced. Unanticipated environmental changes occurred in every major program. The Rio Grande experience points to the need for society to specify goals to which the use of water should contribute and specify priorities for water use among different sectors of river basins and various segments of society.

72-73:02E-007
TRANSPORT OF SOIL PARTICLES BY SHALLOW FLOW,
Foster, G. R., and Meyer, L. D.
United States Department of Agriculture, Agricultural Research Service, Lafayette, Indiana.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, p 99-102, January-February, 1972. 3 fig, 2 tab, 15 ref.

Descriptors: *Erosion, *Soil erosion, *Rill erosion, *Sheet erosion, Sedimentation, Erosion rates, Sediment yield, Sediment load, Sediment transport, Soil conservation.

The Yalin equation was selected to describe the sediment transport capacity of overland flow for use in mathematical soil erosion models. Hydraulic variables in the equation are simply the hydraulic radius and slope steepness. Soil parameters needed are particle diameter, specific gravity, and the critical tractive force from Shields' diagram. When modified to consider mixtures of particle sizes, the equation predicted both the total transport rate and also the particle size distribution of the transported material. When rilling developed, transport rate predictions were within a factor of 2 relative to actual transport rates from a bed of glass spheres. Also, the predicted particle size distributions often agreed well with observed distributions. When applied to a field erosion plot where the sediment load was at transport capacity, the equation predicted sediment load within a factor of 2.

72-73:02E-008
RECESSION FLOW IN SURFACE IRRIGATION,
Wu, I.
Hawaii University, Honolulu, Agricultural Engineering Department.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR1, p 77-90, March, 1972. 6 fig, 1 tab, 9 ref.

Descriptors: *Surface irrigation, *Irrigation efficiency, *Surface runoff, *Recession curves, Furrow irrigation, Border irrigation, Irrigation, Irrigation systems, Irrigation engineering, Irrigation practices, Water, Water storage, Water flow.

The recession flow of furrow or border irrigation can be expressed as a simple power function which is derived by assuming a linear storage of recession flow. The flow length is expressed as a function of recession time and a constant. The knowledge of the length of recession flow profile and recession time is important in the evaluation of irrigation efficiency, especially in the border irrigation which has a relatively large volume of surface storage at the time when the inflow is shut off. Laboratory experiments were conducted and field data of sugarcane furrow experiments were applied to check the validity of the derived mathematical models. A simple recession flow equation is also derived by considering the recession flow as depleting water from a single shallow linear reservoir. For a relatively short length and small slope of furrow or border, the simple recession flow equation seems to be applicable.

72-73:02E-009
A STUDY OF FACTORS INFLUENCING THE NITROGEN AND PHOSPHORUS CONTENTS OF NEBRASKA WATERS,
Muir, J., Seim, E. C., and Olson, R. A.

Nebraska University, Lincoln.
Journal of Environmental Quality, Vol. 2, No. 4, p 466-470, October-December, 1973. 1 fig, 5 tab, 14 ref.
(See 72-73:05B-064)

72-73:02E-010
THEORETICAL IRRIGATION TAILWATER VOLUMES,
Wilke, O.C.
Texas A & M University, Lubbock.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR3, p 415-420, September, 1973. 1 fig.
(See 72-73:03F-047)

72-73:02E-011
NITROGEN AND PHOSPHORUS COMPOSITION OF SURFACE RUNOFF AS AFFECTED BY TILLAGE METHOD,
Romkens, M. J. M., Nelson, D. W., and Mannering, J. V.
United States Department of Agriculture, Agricultural Research Service, Lafayette, Indiana.
Journal of Environmental Quality, Vol. 2, No. 2, p 292-295, April-June, 1973. 2 fig, 4 tab, 12 ref.

Descriptors: *Nitrogen, *Phosphorus, *Leaching, Nutrient removal, Cultivation, Soil management, Fertilizers, Pollutants, Erosion, Sediments.

The effect of tillage methods on the nitrogen and phosphorus composition in runoff water and runoff sediment from corn plots was studied on Bedford silt loam soil by applying simulated rainstorms. Five tillage-planting systems were compared: coulter-plant, till-plant, chisel-plant, disk and coulter-plant, and conventional-plant. The coulter and chisel systems controlled soil loss, but runoff water contained high levels of soluble nitrogen and phosphorus from surface-applied fertilizer. The disk and till systems were less effective in controlling soil erosion, but had lower concentrations of soluble nitrogen and phosphorus in runoff water. Conventional tillage, in which fertilizers were plowed under, had the highest losses of soil and water but small losses of soluble nitrogen and phosphorus. However, high percentages of the total nutrients removed by runoff were components of the sediment from all treatments.

72-73:02E-012
A PROGRAMMED SAMPLER FOR RUNOFF AND BEDLOADS,
Swanson, N. P.
United States Department of Agriculture, Agricultural Research Service, Lincoln, Nebraska.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 4, p 790-792, July-August, 1973. 7 fig, 5 ref.

Descriptors: *Runoff, *Sampling, *Automatic control, Surface runoff, Bedload, Flow, Soil erosion, Water erosion, Water quality, Suspended load, Bedload samplers.

A programmed, automatic sampler that collects a sequence of composite samples of runoff and accompanying bedloads has been in use on a feedlot research installation near Lincoln, Nebraska, for over 4 years. Composited samples are collected over 5-minute sampling periods with volumes of about 3 l. The sampler can be programmed to obtain individual samples for any 14 5-minute periods during a total of 12 hours of actual runoff. The runoff need not be continuous. The time of collection of each sample is recorded to relate to the runoff hydrograph and recording rain-gage chart. Bedload particles up to 5/8 inch in diameter can enter the rotating sampler dipper, which passes under the discharge.

72-73:02E-013
MODELING OF LAND RUNOFF EFFECTS ON DISSOLVED OXYGEN,
Wallace, D. A., and Dague, R. R.
Kansas State University, Civil Engineering Department, Manhattan.
Journal Water Pollution Control Federation, Vol. 45, No. 8, p 1795-1809,
August, 1973. 17 fig, 7 tab, 10 ref.

Descriptors: *Computer models, *Runoff, *Water pollution sources, Mathematical models, Agricultural runoff, Agricultural watersheds, Water quality, Erosion.

A computer mathematical model to estimate the effects of agricultural land runoff on river dissolved oxygen (DO) concentrations has been developed. The Iowa River basin above the Coralville Reservoir was chosen as the area on which to base the model. This area includes 237 miles of main-stem channel and 44 tributaries draining 2,953 square miles. About 90 percent of the area is used for farming operations. The model accounts for both surface and subsurface inflows. Principles of open channel flow are used to describe the flow conditions in the river. The model approximates actual river conditions and is useful in showing the relative effects of different sources of pollution.

72-73:02E-014
THE INTER-RELATIONSHIP OF WATER QUANTITY AND QUALITY AS A DETERMINANT OF WATER MANAGEMENT POLICY,
Gordon, Y.
The Mitre Corporation, Westgate Research Park, McLean, Virginia.
Water Research, Vol. 16, No. 12, p 1501-1508, December, 1972. 1 fig, 2 tab,
5 ref.

Descriptors: *Water quality, *Salinity, Water supply, Irrigation, Colorado River Basin, Colorado River. Water pollution sources.

Comprehensive water resources management includes a variety of factors, among which are water quantity and quality, institutional and legal aspects, and economics. Even though water quality has begun to attin some prominence, its relation to water quantity and to water system operation has been largely overlooked. The Colorado River system inthe United States is a case in point. The river basin encompasses an area which is one-twelfth the size of the continental United States. The water is utilized mainly for irrigation of semi-arid areas in the southwestern part of the United States and in northwestern Mexico. Despite its importance, the river system operates under laws and regulations that are not conducive to efficiency. Consequently water is used wastefully and a progressive deterioration in the quality of the river water is evident. Changes in water management are recommended. The pricing of supplied water according to its quality as well as charges for pollution are suggested.

Section VI

WATER CYCLE

GROUNDWATER (Group 02F)

72-73:02F-001
LAND SUBSIDENCE IN THE WESTERN STATES DUE TO GROUNDWATER OVERDRAFT,
Poland, J. F.
Geological Survey, Sacramento, California
Water Resources Bulletin, Vol. 8, No. 1, p 118-131, February 1972. 11 fig, 11 ref.

Descriptors: *Subsidence, *Land subsidence, *Withdrawal, *Groundwater, Water table, Confined water, Irrigation water, Water wells, History, Reviews, Artificial recharge.

Development of farm lands in most of the western states has required irrigation by surface water or groundwater, supplemental to precipitation. Pumping draft has exceeded replenishment in many areas. Water levels have been drawn down from 100 to 500 feet, greatly increasing the grain-to-grain stress or effective overburden load on the aquifer systems in which the head depletion has occurred. This increase in stress tends to cause compaction of the deposits and subsidence of the land surface. The aquifer systems in the western states that have experienced appreciable compaction are chiefly confined systems. Subsidence can be stopped by raising water levels sufficiently to eliminate excess pore pressures in the fine-grained compressible interbeds and confining beds. In areas of groundwater overdraft, this can be accomplished by a reduction of withdrawal, or an increase in recharge, or both, in an amount exceeding the overdraft. In several areas, importation of a supplemental supply has been the solution.

72-73:02F-002
APPLICATION OF GALERKIN'S PROCEDURE TO AQUIFER ANALYSIS
Pinder, G. F., and Frind, E. O.
Geological Survey, Washington, D.C.
Water Resources Research, Vol. 8, No. 1, p 103-120, February 1972. 10 fig, 2 tab, 21 ref.

Descriptors: *Groundwater movement, *Numerical analysis, Mathematical studies, Equations, Aquifer characteristics, Hydraulic conductivity, Transmissivity, Water yield, Drawdown, Mathematical models.
Identifiers: Finite difference method, *Galerkin procedure.

Groundwater flow equations may be solved using the Galerkin procedure to generate the approximating equations. The integrals in the resulting equations may be efficiently evaluated by using isoparametric quadrilateral elements and numerical integration. A comparison of solutions for an idealized problem obtained by using Galerkin techniques and finite difference techniques indicates they achieve approximately the same degree of accuracy. A field application of the two methods shows that the Galerkin procedure provides satisfactory solutions with far fewer nodes than were required for the finite difference approach. In selecting a method for a particular hydrologic problem the flexibility of the irregular subspaces used in the Galerkin approach must be weighed against the very efficient equation-solving schemes applicable to the finite difference equations.

72-73:02F-003
DRAWDOWN DISTRIBUTION AROUND WELLS PARTIALLY PENETRATING THICK LEAKY ARTESIAN AQUIFERS,
Halepaska, J. C.
New Mexico Institute of Mining and Technology, Socorro, Department of Geoscience.
Water Resources Research, Vol. 8, No. 5, p 1332-1337, October 1972. 2 fig, 14 ref.

Descriptors: *Groundwater movement, *Artesian aquifers, *Numerical analysis, Drawdown, Transmissivity, Hydraulic conductivity, Storage coefficient, Mathematical studies.
Identifiers: *Leaky artesian aquifers.

The differential equation governing nonsteady flow to a well in a thick leaky system was solved by using transform techniques. Routines to tabulate the most general solution in type curve form were developed and are available. The limiting curve of the tabulated function is the Hantush partial penetration type-curve. With knowledge of the geologic framework the technique can be applied to certain field problems.

72-73:02F-004
SOLUTIONS OF HYDRODYNAMIC DISPERSION IN POROUS MEDIA,
Eldor, M., and Dagan, G.
Technion-Israel Institute of Technology, Haifa.
Water Resources Research, Vol. 8, No. 5, p 1316-1331, October 1972. 9 fig, 13 ref.

Descriptors: *Dispersion, *Tracers, *Radioisotopes, *Adsorption, *Groundwater movement, Radioactivity, Mixing, Numerical analysis, Aquifer testing, Mathematical studies, Hydrogeology, Water chemistry.

Problems of hydrodynamic dispersion of tracers in porous media with radioactive decay and adsorption of the tracer are solved by an approximate analytical method. The flow of the carrier fluid is assumed to be steady and two dimensional. Initially a sharp front separates two regions of different constant tracer concentrations. By means of the method of outer and inner expansions, approximate analytical solutions of dispersion with adsorption and radioactive decay of the tracer have been determined. The method has been used for a few examples of steady two-dimensional flows encountered in hydrologic applications. Existing numerical solutions are in good agreement with the present results. The method can be extended to solve more complex problems, including tracers that influence the velocity field by changing the density and the viscosity of the carrier, nonlinear adsorption isotherms, and three-dimensional flows.

72-73:02F-005
VISCOUS FLOW MODEL FOR GROUNDWATER MOVEMENT,
Yen, B. C., and Hsie, C. H.
Illinois University, Urbana, Department of Civil Engineering.
Water Resources Research, Vol. 8, No. 5, p 1299-1306, October 1972. 3 fig, 14 ref.

Descriptors: *Hydraulic models, *Groundwater movement, Laminar flow, Porous media, Viscosity, Reynolds number, Stokes law, Hydraulic similitude.

Identifiers: *Hele-Shaw models, Viscous flow models.

A viscous flow model with nonuniform spacing between plates can be used to simulate two-dimensional laminar flow in heterogeneous porous media. Such a model can also be used to study the effects of aquifer thickness on flow in homogeneous porous media. Mathematical expressions were developed from equations of motion and continuity for flow in porous media and for flow between closely spaced nonparallel plates to verify the theoretical background of such model simulations. The modeling is valid for groundwater flow that obeys Darcy's law and viscous flow between plates with the Reynolds number within the Stokes range.

72-73:02F-006
FIELD DETERMINATION OF THE HYDRAULIC PROPERTIES OF LEAKY MULTIPLE AQUIFER SYSTEMS,
Neuman, S. P., and Witherspoon, P. A.
Volcani Institute of Agricultural Research, Bet-Dagn (Israel).
Water Resources Research, Vol. 8, No. 5, p 1284-1298, October 1972. 9 fig, 4 tab, 21 ref.

Descriptors: *Aquifer testing, *Artesian aquifers, *Confined water, *Aquitards, *Testwells, Water levels, Drawdown, Hydraulic conductivity, Storage coefficient, Transmissivity, Observation wells, Aquifer characteristics, Hydrogeology, *California.
Identifiers: *Leaky artesian aquifers.

A new field method is proposed for determining the hydraulic properties of aquifers and aquitards in leaky systems. Conventional methods of analyzing leaky aquifers usually rely on drawdown data from the pumped aquifer alone. Such an approach is not sufficient to characterize a leaky system; the method requires observation wells to be placed not only in the aquifer being pumped but also in the confining layers (aquitards). The ratio of the drawdown in the aquitard to that measured in the aquifer at the same time and the same radial distance from the pumping well can be used to evaluate the hydraulic properties of the aquitard. The new method is supported by theory and has been applied to the coastal groundwater basin of Oxnard, California. The field results are in good agreement with laboratory measurements.

72-73:02F-007
RADIAL FLOW IN AN INFINITE AQUIFER UNDERGOING CONVERSION FROM ARTESIAN TO WATER TABLE CONDITIONS,
Moench, A. F., and Prickett, T. A.
Illinois State Water Survey, Urbana.
Water Resources Research, Vol. 8, No. 2, p 494-499, April 1972. 4 fig, 1 tab, 5 ref.

Descriptors: *Groundwater movement, *Artesian aquifers, *Withdrawal, *Water table, *Drawdown, Water yield, Artesian heads, Aquifer systems, Confined water, Pressure, Diffusion, Transmissivity, Dupuit-Forchheimer theory, Mathematical studies, Water storage.
Identifiers: Heat-flow equations.

A closed form mathematical solution is given for water level conversion from artesian to water table conditions due to a well discharging at a constant rate. The solution is obtained from the analogous case of heat flow in cylindrical symmetry in which freezing or melting takes place. A single nonleaky artesian aquifer that is homogeneous isotropic, and infinite in areal extent is considered. The well fully penetrates the aquifer and is infinitesimal in diameter. Dimensionless curves are given, and suggestions are made to aid in the analysis and interpretation of the aquifer test data.

72-73:02F-008
USE OF NATURALLY OCCURRING PHENOMENA TO STUDY HYDRAULIC DIFFUSIVITIES OF AQUITARDS,
Davis, R. W.
Southern Illinois University, Carbondale, Department of Geology.
Water Resources Research, Vol. 8, No. 2, p 500-507, April 1972. 4 fig, 2 tab, 15 ref.

Descriptors: *Barometric efficiency, *Artesian aquifers, *Aquitards, *Water level fluctuations, *Aquifer testing, Aquifer systems, Hydrogeology, Drawdown, Permeability, Porosity, Confined water, Florida.
Identifiers: *Pasco County (Fla).

Measurement of the response of an artesian aquifer system to naturally occurring stress fields can be used to determine aquitard properties. The response of an artesian aquifer to a short-term rise of water levels can be estimated by approximating a step function in the unconfined aquifer above it. An analysis of the corresponding change in artesian water levels gives a value for the aquitard hydraulic diffusivity divided by the square of the aquitard thickness. This method is demonstrated by using data from a well field in Pasco County, Florida. A second method uses the response of an artesian system to barometric or tidal stresses, which is frequency dependent. It is necessary to restrict Jacob's definition of barometric and tidal efficiencies to instantaneous stress changes. The methods described are easily applied and serve to check the values of a boundary condition that is assumed to be homogeneous in other analytical approaches.

72-73:02F-009
GROUNDWATER FLOW IN AN INHOMOGENEOUS AQUIFER,
Kuiper, L. K.
Iowa State Geological Survey, Iowa City.
Water Resources Research, Vol. 8, No. 3, p 722-724, June 1972. 1 fig, 4 ref.

Descriptors: *Groundwater movement, *Hydraulic conductivity, *Heterogeneity, *Aquifer characteristics, Numerical analysis, Mathematical models.
Identifiers: *Inhomogeneous aquifers.

An analytic solution was obtained for the groundwater head in a confined inhomogeneous and isotropic aquifer of constant thickness. The vertical direction component of the groundwater flow is assumed to be zero. The specific storage is assumed to be a constant. The hydraulic conductivity varies with distance of flow. The solution is compared graphically with the solution for the case where hydraulic conductivity is constant and an impermeable boundary exists. Head approaches its final value more rapidly for constant variable hydraulic conductivity.

72-73:02F-010
SOLUTION OF TRANSIENT GROUNDWATER FLOW PROBLEMS BY THE FINITE ELEMENT METHOD,
Verruijt, A.
Technische Hogeschool, Delft (Netherlands).
Water Resources Research, Vol. 8, No. 3, p 725-727, June 1972. 8 ref.

Descriptors: *Unsteady flow, *Groundwater movement, *Numerical analysis, Mathematical models, Hydraulic conductivity, Water storage, Infiltration, Finite element analysis.

The derivation of the basic equations of a finite element method for transient groundwater flow problems is simplified when the approximation of the time derivative by a finite difference equation is made before the introduction of the variational principle. Existing programs for steady state problems can easily be extended to the transient case in this way, and a stable numerical procedure can be obtained.

72-73:02F-011
DRAWDOWN IN A FINITE CIRCULAR AQUIFER WITH CONSTANT WELL DISCHARGE,
Kuiper, L. K.
Iowa State Geological Survey, Iowa City.
Water Resources Research, Vol. 8, No. 3, p 734-736, June 1972. 1 fig, 4 ref.

Descriptors: *Drawdown, *Transmissivity, *Numerical analysis, Groundwater movement, Unsteady flow, Withdrawal, Storage coefficient, Discharge (Water).

An analytical solution is derived for the groundwater head in a confined homogeneous, isotropic aquifer with a constant thickness and a circular impermeable boundary around a well penetrating the entire depth of the aquifer and discharging at a constant rate. The solution is compared with the Theis solution, which is valid for an aquifer of unlimited extent. The two solutions agree very closely at small radial distance.

72-73:02F-012
UNSTEADY RADIAL FLOW IN AN UNCONFINED AQUIFER,
Streltsova, T. D.
Birmingham University (England), Department of Civil Engineering
Water Resources Research, Vol. 8, No. 4, p 1059-1066, August 1972. 2 fig, 14 ref.

Descriptors: *Groundwater movement, *Drawdown, *Unsteady flow, *Water table, Equations, Saturated flow, Unsaturated flow, Storage, Permeability, Storage coefficient, Water level fluctuations, Numerical analysis.
Identifiers: *Unconfined aquifers.

Partial differential equations were written for unsteady radial flow to a well that is tapping an unconfined aquifer of infinite extent and discharging at a constant rate. Complete penetration of the aquifer by the well is assumed. Consideration is given to the observed head in a well that is screened throughout the unconfined aquifer, as well as to the head that corresponds to the free surface value. A relationship between the observed head and the free surface head is assumed to have the form of a vertical transfer linear equation.

72-73:02F-013
SOURCE AREAS AND CLIMATIC EFFECTS IN CARBONATE GROUNDWATERS DETERMINED BY SATURATION INDICES AND CARBON DIOXIDE PRESSURES,
Shuster, F. T., and White, W. B.
Pennsylvania State University, University Park, Department of Geosciences.
Water Resources Research, Vol. 8, No. 4, p 1067-1073, August 1972. 8 fig, 1 tab, 8 ref.

Descriptors: *Water chemistry, *Karst hydrology, *Limestones, *Carbonate rocks, *Pennsylvania, Dolomite, Leaching, Carbon dioxide, Springs, Groundwater, Geochemistry, Karst.
Identifiers: *Nittany valley (Pennsylvania).

In 14 carbonate springs in Nittany valley in central Pennsylvania, the feeder system for the springs can be characterized as conduit flow or diffuse flow on the basis of the variability in water chemistry. Saturation indices and CO2 partial pressures were sorted into monthly groups and averaged. Conduit springwaters are always aggressive with respect to both calcite and dolomite. The high variability reflects mostly variation in recharge, short residence time, and slow kinetics of equilibration between water and rock. Diffuse springwaters are somewhat aggressive with respect to calcite during the growing season but become somewhat supersaturated during the winter. Waters from diffuse-flow springs in dolomite are nearly at saturation, whereas waters from diffuse-flow springs in limestone are always undersaturated with respect to dolomite. The equilibrium CO2 pressures of conduit springwaters show a regular seasonal trend having a pronounced maximum during the growing season. The CO2 content of diffuse-flow springs is highly variable, and although the summer maximum is present, the CO2 content also reflects variations in the CO2 production in the catchment areas of infiltrating waters.

72-73:02F-014
USE OF SUBJECTIVE INFORMATION IN ESTIMATION OF AQUIFER PARAMETERS,
Lovell, R. E., Duckstein, L., and Kisiel, C. C.
Arizona University, Tucson, Department of Hydrology and Water Resources; and Arizona University, Tucson, Department of Systems Engineering.
Water Resources Research, Vol. 8, No. 3, p 680-690, June 1972. 3 fig, 4 tab, 13 ref.

Descriptors: *Mathematical models, *Calibrations, *Hydrogeology, *Aquifer characteristics, Parametric hydrology, Groundwater movement, Water yield, Model studies, Water levels, Numerical analysis.

In the calibration of aquifer models, the desire for an automated adjustment process is sometimes in conflict with the need for subjective intervention during the calibration process. Working from the established concept of modeling for unconfined aquifers with rectangular nodes, a method is described of obtaining subjective information in addition to that customarily used in model calibration. Such information is assembled and quantified at the same time as the usual data are gathered for initial estimation of parameters. This information is then introduced into an automatic adjustment process in such a way that the calibration process can proceed without interruption until the desired level of relative accuracy is reached, or until it is shown that the desired level cannot be reached within the constraints assigned. A decoupling technique that permits simultaneous adjustment of all parameters is also described. A digital computer model of the Tucson basin aquifer is used to illustrate the concepts and demonstrate the adjustment method.

72-73:02F-015
DIGITAL SIMULATION OF THE BOUSSINESQ EQUATION FOR A WATER TABLE AQUIFER,
Lin, C. L.
Nova Scotia Department of Mines, Halifax.
Water Resources Research, Vol. 8, No. 3, p 691-698, June 1972. 5 fig, 16 ref.

Descriptors: *Simulation analysis, *Groundwater movement, Numerical analysis, Dupuit-Forchheimer theory, Water levels, Permeability, Unsteady flow, Water yield, Mathematical models, Drawdown.
Identifiers: *Boussinesq equation.

A mathematical model was developed to simulate the Boussinesq equation for a two-dimensional water table aquifer. Transient solutions to the finite difference approximations based on an irregular mesh matrix were obtained by the alternating direction implicit method. The precision of the model was evaluated by comparing the volume of water pumped with the amount of water released from storage and the amount received from a nearby recharging river. The model is suitable for the study of transient flow in a permeable sand and gravel aquifer.

72-73:02F-016
MODELING THE PORE STRUCTURE OF POROUS MEDIA,
Farrell, D. A., and Larson, W. E.
Agricultural Research Service, St. Paul, Minnesota, Soil and Water Conservation Research Division.
Water Resources Research, Vol. 8, No. 3, p 699-706, June 1972. 2 fig, 19 ref.

Descriptors: *Porous media, *Mathematical models, *Hydraulic conductivity, Saturated flow, Unsaturated flow, Pores, Groundwater movement, Soil water movement, Porosity, Capillary action, Capillary conductivity, Diffusion.
Identifiers: *Pore structure.

A physicomathematical alternative to capillaric modeling of the pore structure of porous media is proposed. With this model, the hydraulic conductivity of porous materials is determined from a 'pore domain' characterization of the pore space by using an appropriate conductance theory for estimating the flux contribution of the various components of heterogeneous media. The proposed model is versatile yet mathematically tractable and is capable of analyzing fluid flow through porous materials of widely differing structure including anisotropic and structured media. A comparative study of the predictions of this model with those of a model widely used in soil science is made for several media. Indiscriminate use of the soil water model may be responsible for the gross overpredictions of hydraulic conductivity for some porous materials and also for the reported distortions in the relationships between conductivity and the degree of saturation for some soils.

72-73:02F-017
ACCOUNTING FOR APPARATUS-INDUCED DISPERSION IN ANALYSES OF MISCIBLE DISPLACEMENT EXPERIMENTS,
James, R. V. and Rubin, J.
Geological Survey, Menlo Park, California, Water Resources Division.
Water Resources Research, Vol. 9, No. 3, p 717-721, June 1972. 4 fig, 1 tab, 14 ref.

Descriptors: *Dispersion, *Path of pollutants, *Porous media, *Saturated flow, *Unsaturated flow, Mixing, Stratified flow, Solutes, Calibrations, Laboratory tests, Equipment, Saline water intrusion, Saline water-freshwater

interfaces.
Identifiers: *Miscible displacement.

In studies of hydrodynamic dispersion in porous media there is some difficulty in theoretically predicting experimental breakthrough curves from laboratory columns. The greatest discrepancies occur for short-column experiments or studies of unsaturated media. Some of the disagreement can be eliminated by a quantitative treatment of apparatus-induced dispersion. The experimental system is treated as a two-layer construct in which the porous medium and the apparatus are considered as separate layers. The dispersion characteristics of the apparatus layer are determined independently in the absence of the porous material. The dispersion coefficient for the porous medium is obtained from a two-layer dispersion equation. The hydrodynamic dispersion coefficients calculated in this manner are as much as 40% lower than those obtained by the usual one-layer approach.

72-73:02F-018
NUMERICAL SIMULATION OF FLOW IN AN AQUIFER OVERLAIN BY A WATER TABLE AQUITARD,
Cooley, R. L.
Nevada University, Reno, Center for Water Resources Research.
Water Resources Research, Vol. 8, No. 4, p 1046-1050, August 1972. 1 fig, 9 ref.

Descriptors: *Groundwater movement, *Water table, *Compressibility, *Water level fluctuations, *Drawdown, Permeability, Storage coefficient, Numerical analysis, Unsaturated flow, Saturated flow, Mathematical models.
Identifiers: *Unconfined aquifers.

An extension of the convolution integral produced by 'delayed yield' theory describes vertical flow rate at the base of a unit such as an aquitard bounded at the top by a water table across which recharge is permitted and at the bottom by a variable drawdown boundary. The solution requires that the water table release water from storage instantaneously with a decline in head and that the compressibility of both the unit and the water in it be neglected. Application of the integral as an upper boundary condition for an aquifer underlying a water table aquitard allows approximation of the influence of the water table aquitard on the unsteady state head distribution in the aquifer. A simple, efficient procedure permits the use of a numerical approximation of the integral with a numerical groundwater flow model of the aquifer. An example solution demonstrates the high degree of accuracy of the method.

72-73:02F-019
DETERMINATION OF THE HYDRAULIC DIFFUSIVITY OF A HETEROGENEOUS CONFINING BED,
Wolff, R. G., and Papadopulos, S. S.
Geological Survey, Washington, D.C.
Water Resources Research, Vol. 8, No. 4, p 1051-1058, August 1972. 6 fig, 5 tab, 11 ref.

Descriptors: *Groundwater movement, *Diffusivity, *Aquicludes, *Aquitards, *Artesian aquifers, Permeability, Numerical analysis, Mathematical models, Piezometers, Groundwater, Confined water.
Identifiers: *Leaky artesian aquifers.

The hydraulic diffusivity of a confining bed exhibiting vertical heterogeneity was determined by field and laboratory tests. A thin sand aquifer was pumped, and head changes were observed in the aquifer and at three vertically separated piezometers in the overlying confining bed. A four-layer digital model was used to analyze the field data. Hydraulic diffusivities for each layer were adjusted in the model until calculated head changes in all piezometers closely matched those observed in the field. Laboratory-determined hydraulic diffusivities were several orders of magnitude smaller than the field-determined values. Interfingering of layers within the confining bed is believed to have caused this difference. Additional studies are needed before a general conclusion can be reached on the value of laboratory determinations of hydraulic parameters for heterogeneous confining beds.

72-73:02F-020

THEORY OF FLOW IN UNCONFINED AQUIFERS CONSIDERING DELAYED RESPONSE OF THE WATER TABLE,

Neuman, S. P.
Volcani Institute of Agricultural Research, Bet-Dagan (Israel), Department of Soil and Water.
Water Resources Research, Vol. 8, No. 4, p 1031-1045, August 1972. 12 fig, 37 ref.

Descriptors: *Groundwater movement, *Water table, *Compressibility, *Water level fluctuations, *Drawdown, Permeability, Storage coefficient, Numerical analysis, Unsaturated flow, Saturated flow, Mathematical models.
Identifiers: *Unconfined aquifers.

A new analytical model is proposed for the delayed response process characterizing flow to a well in an unconfined aquifer. The present approach is based only on well-defined physical parameters of the aquifer system. Therefore it provides a possible physical explanation for the mechanism of delayed water table response. The process of delayed response in a homogeneous anisotropic phreatic aquifer can be simulated by using constant values of specific storage and specific yield without recourse to unsaturated flow theory. In the absence of significant infiltration at the ground surface, compressibility may often be a much more important factor than unsaturated flow above the water table.

72-73:02F-021

SUBSURFACE HYDROGRAPH ANALYSIS BY CONVOLUTION,

Snyder, W. M., and Asmussen, L. E.
Agricultural Research Service, Athens, Georgia, Southeast Watershed Research Center.
American Society of Civil Engineers, Journal of the Irrigation and Drainage Division, Vol. 98, No. IR3, p 405-418, September 1972. 7 fig, 3 tab, 9 ref.

Descriptors: *Hydrograph analysis, *Infiltration, *Subsurface runoff, *Mathematical models, *Rainfall-runoff relationships, Routing, Numerical analysis, Irrigation, Subsurface irrigation, Coastal plains, *Georgia.
Identifiers: Convolution integrals.

Subsurface flow from an 0.8-acre watershed in the Southern Coastal Plain at Tifton, Georgia is intercepted and gaged independently of any surface flows. The hydrographs of seven flow events following significant rainfall were analyzed by the nonlinear technique of two-stage convolution. The convolutional model is based on two conceptual components. A characteristic function represents the three-dimensional storage capability of the soil profile and thus could be visualized as a map of the flow potential of the drainage area. A state function expresses the movement, or routing, of the characteristic function to the outlet. This routing is the first-stage convolution and produces a unit response function. Second-stage convolution of the response functions with effective rainfall produces the outflow hydrograph. The consistent results should allow identification of the parameters, and thus the two quasi-physical model components, with physical features of the drainage area.

72-73:02F-022
UNCONFINED FLOW THROUGH JOINTED ROCK,
Castillo, E., Karadi, G.M., and Krizek, R. J.
Water Resources Bulletin, Vol. 8, No. 2, p 266-281, April 1972. 13 fig, 1 tab, 9 ref.

Descriptors: *Groundwater movement, *Joints (Geologic), Fractures (Geologic), *Mathematical models, *Numerical analysis, Laminar flow, Turbulent flow, Permeability, Viscosity, Density, Roughness (Hydraulic).

The two-dimensional, steady-state, unconfined flow of a homogeneous fluid through jointed rock was studied for both laminar and turbulent conditions by use of a method which is based on theoretical and experimental flow relationships. Only the independent unknowns are computed in order to reduce the complexity of the problem and render it more readily tractable. The intact rock is assumed to be impermeable, and two intersecting systems of plane, parallel joints are responsible for all permeability in the mathematical model, taking into account the surface roughness of the joints. The mathematical solution of the resulting nonlinear system of equations is obtained by use of a rapidly converging iterative procedure, in which each iteration takes special advantage of the banded nature of the associated matrix. For the particular case in which a free surface exists, the general flow equations are not satisfied, because some of the joints in the vicinity of the free surface do not flow full; therefore, new equations must be established to handle this condition. Once the development of the mathematical model is accomplished, several cases involving different geometric characteristics (width, orientation, and roughness of joints) are solved for a rectangular domain, and graphs are given to illustrate the influence of the various parameters on the manifested flow behavior.

72-73:02F-023
DEEP PERCOLATION IN A SAND HILL AREA,
Glover, R. E.
Colorado State University, Fort Collins, Department of Civil Engineering.
Water Resources Bulletin, Vol. 8, No. 2, p 399-400, April 1972. 6 ref.

Descriptors: *Percolation, *Recharge, *Infiltration, *Water balance, *Surface-groundwater relationships, Nebraska, Great Plains, Water yield, Sands.
Identifiers: *Sand Hills (Nebraska), Ogallala Formation.

Infiltration into the Ogallala aquifer in Nebraska was calculated using records for two rivers flowing in a Sand Hill area. The infiltration is 0.23 feet per year, which is 13% of the precipitation. Weather Bureau records for Halsey based on 58 years or observation yield an average precipitation rate of 20.73 inches per year or 1.727 feet per year. In this area the deep percolation represents 0.134 of the precipitation.

72-73:02F-024
ROLE OF SUBSURFACE FLOW IN GENERATING SURFACE RUNOFF. 2. UPSTREAM SOURCE AREAS,
Freeze, R. A.
Thomas J. Watson Research Center, Yorktown Heights, New York.
Water Resources Research, Vol. 8, No. 5, p 1272-1283, October, 1972. 11 fig, 27 ref.
(See 72-73:02A-002)

72-73:02F-025
IDENTIFICATION OF PARAMETERS IN FINITE LEAKY AQUIFER SYSTEM,
Marine, M. A. and Yeh, W. W. G.
California University, Los Angeles, Department of Engineering Systems.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY2, Paper 9567, p 319-336, February 1973. 5 fig, 5 tab, 15 ref, append.

Descriptors: *Artesian aquifers, *Finite element analysis, *Numerical analysis, Transmissivity, Storage coefficient, Parametric hydrology, Systems analysis, Aquifer characteristics, Groundwater movement, Leakage.
Identifiers: *Leaky aquifers.

Many methods for analyzing leaky artesian systems are graphical procedures which involve invlection-point estimation and extrapolation of field data, or superposition and matching, or both, of field data to a family of theoretical curves. A systematic procedure for the identification of aquifer parameters in a finite leaky artesian system converts field observations directly to system parameters. The parameters to be identified are the transmissivity and storativity of the main aquifer, and the leakage factor of the system. The algorithm involves finite difference approximation and quasilinearization in conjunction with least-squares optimization. Examples that demonstrate the applicability of the algorithm are presented.

72-73:02F-026
DISPERSION IN NONUNIFORM SEEPAGE,
Hunt, B. W.
Canterbury University, Christchurch (New Zealand), Department of Civil Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY2, Paper 9553, p 295-299, February 1973. 7 ref, append.

Descriptors: *Dispersion, *Seepage, *Non-Uniform flow, *Groundwater movement, *Path of pollutants, Mixing, Mathematical models, Equations, Numerical analysis.

General equations are derived which describe the dispersion of a pollutant in three-dimensional, nonuniform seepage. These equations are obtained by assuming that the principal directions of the dispersion tensor are tangential and normal to the streamlines, and the final result is shown to agree with the results of previous investigators only when the principal values of the dispersion tensor are written in a form which, in general, may not agree with experimental results. The advantages of using this model to compute numerically the concentrations of a pollutant from piezometric head field data are pointed out.

72-73:02F-027

GRAVITATIONAL AND DISPERSIVE MIXING IN AQUIFERS,

Gelhar, L. W., Wilson, J. L., and Miller, J. S.

Massachusetts Institute of Technology, Cambridge, Department of Civil Engineering.

Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 98, No. HY12, Paper 9439, p 2135-2153, December 1972. 7 fig, 2 tab, 12 ref, append.

Descriptors: *Mixing, *Artificial recharge, *Dispersion, *Recharge wells, Path of pollutants, Injection wells, Stratified flow, Water quality, Density stratification, Convection, Groundwater movement, Hydraulics, Water storage.

Analytical techniques were developed to describe the mixing between two fluids of different density in a confined aquifer, in which one fluid is introduced to the aquifer by well recharge. The immiscible displacement process in radial flows was analyzed. The effects of longitudinal and lateral dispersion are included using a boundary layer approximation. The theoretical results were compared with observations of aquifer mixing in a laboratory model. Excellent agreement between the theoretical predictions and experimental results was found. Theoretical predictions of recovery efficiency during a recharge-storage-withdrawal cycle show trends similar to those observed, but are somewhat lower. Direct theoretical predictions of recovery efficiency were developed for an immiscible system.

72-73:02F-028

STEADY SEEPAGE FLOW TO SINK PAIRS SYMMETRICALLY SITUATED ABOVE AND BELOW A HORIZONTAL DIFFUSING INTERFACE: 1. PARALLEL LINE SINKS,

Wolanski, E. J., and Wooding, R. A.

Johns Hopkins University, Baltimore, Maryland, Department of Environmental Engineering.

Water Resources Research, Vol. 9, No. 2, p 415-425, April 1973. 7 fig, 16 ref.

Descriptors: *Saline water-freshwater interfaces, *Diffusion, *Groundwater movement, *Saline water intrusion, Dispersion, Encroachment, Withdrawal, Steady flow, Saturated flow, Safe yield, Boundary layers.

The flow regime close to a pair of wells situated on opposite sides of a diffusing interface between freshwater overlying saline water is illustrated using an idealized symmetrical system. The interface is horizontal, and gravitational effects are neglected. A uniform flow is parallel to the interface, and the fresh and saline fluids are seperated by a thin impermeable layer at a finite distance upstream from the sinks. The edge of the impermeable layer provides a definite starting point for diffusive mixing at the interface. As part of a largescale gravity system, flow in the upper fluid should bear a qualitative resemblance to real situations where freshwater is moving slowly over nearly stationary saltwater. Boundary layer theory is used to treat the growth of the diffusive mixing layer, modified by the presence of the sinks. The flux of salt to the upper sink is calculated as a function of the spacing and strength of the uniform flow. A periodic system of sink pairs without an applied flow is also considered. Exact solutions of the boundary layer equations are readily obtained for the two-dimensional case.

72-73:02F-029

UNSTEADY FLOW TO A PARTIALLY PENETRATING, FINITE RADIUS WELL IN AN UNCONFINED AQUIFER,

Kipp, K. L. Jr.
Washington University, Seattle.
Water Resources Research, Vol. 9, No. 2, p 448-462, April 1973. 8 fig, 18 ref.

Descriptors: *Unsteady flow, *Groundwater movement, *Equations, *Water yield, *Drawdown, Saturated flow, Mathematical studies, Numerical analysis, Water wells, Hydraulic conductivity, Aquifer testing, Hydrogeology.
Identifiers: *Partially penetrating wells.

Unsteady flow to a single, partially penetrating well of finite radius in an unconfined aquifer is solved theoretically. The aquifer is homogeneous, isotropic, and infinite both in thickness and lateral extent. Perturbation expansion techniques linearize the free surface boundary conditions, so that the solution satisfies the boundary conditions through first order provided that the drawdowns remain small, and that a time limit is imposed. The basic potential field is created by distributing dipole moments over the surface of the well bore and solving the resulting integral equation numerically. The solution can be used to model pumped well behavior for the initial period after the start of pumping. This solution is not restricted to the constant flow rate or constant head modes of simulation. The assumption of constant discharge operation in earlier, more approximate solutions to this problem is more realistic than the assumption of constant head operation.

72-73:02F-030

MASS TRANSPORT IN FLOWING GROUNDWATER,

Bredehoeft, J. D., and Pinder, G. F.
Geological Survey, Lakewood, Colorado
Water Resources Research, Vol. 9, No. 1, p 194-210, February 1973. 20 fig, 18 ref.

Descriptors: *Path of pollutants, *Artesian aquifers, *Georgia, *Groundwater movement, *Saline water intrusion, Encroachment, Mathematical models, Mass transfer, Saline water, Withdrawal, Hydrologic budget.
Identifiers: *Brunswick (Georgia).

The mass transport equation and the equation of motion were coupled and solved numerically for a saturated isothermal groundwater system in which there are no chemical reactions. A case history of groundwater contamination at Brunswick, Georgia, illustrates the use of this physical-chemical model in predicting and controlling the future movement of contaminants. The principal artesian aquifer in the Brunswick area is composed of permeable zones in the Ocala and underlying limestones of Clairborne age. At least three more or less isolated zones are recognized. The permeable zones are separated from one another by dense limestones. The units that act as aquifers are highly permeable; caverns have been detected in each. Both the upper and lower water-bearing zones show areas of saltwater contamination. The source of the water is the underlying brackish water zone, the water migrating upward through two natural conduits. These conduits may be associated with a fault. The most feasible measure to protect the well field is to put interceptive pumping in the aquifer between the source of contamination and the pumping center.

72-73:02F-031

EFFECT OF NONLINEAR STABILIZING SALINITY PROFILES ON THERMAL CONVECTION IN A POROUS MEDIUM LAYER,

Rubin, H.

Technion - Israel Institute of Technology, Haifa, Department of Civil Engineering.

Water Resources Research, Vol. 9, No. 1, p 211-221, February 1973. 5 fig, 2 tab, 9 ref.

Descriptors: *Convection, *Path of pollutants, *Saline water intrusion, *Porous media, Mixing, *Dispersion, Groundwater movement, Density stratification, Aquifers, Stratified flow, Mass transfer, *Salinity.

Nonlinear salinity profiles may exist in an aquifer when salt water and fresh water are brought into contact. They may be maintained indefinitely by a horizontal flow. The effect of such salinity profiles on marginal stability and overstability, as well as on thermal convection, was investigated. Nonlinearity of the salinity profile affects the stability criteria of the field and changes the shape of the convective cells appearing at instability. Nonlinearity of the profiles may increase the stability more than in the linear case for small values of the Rayleigh number.

72-73:02F-032

FUNCTIONAL COEFFICIENTS IN THE ANALYSIS OF GROUNDWATER FLOW,

Pinder, G. F., Frind, E. O., and Papadopulos, S. S.

Princeton University, New Jersey, Department of Civil and Geological Engineering.

Water Resources Research, Vol 9, No. 1, p 222-226, February 1973. 3 fig, 3 ref.

Descriptors: *Groundwater movement, *Finite element analysis, *Mathematical studies, Variability, Numerical analysis, Porous media.
Identifiers: Galerkin theory.

Although finite element techniques in groundwater flow analyses generally require constant aquifer parameters over each element, variable properties can be handled easily by using isoparametric quadrilateral elements in conjunction with approximating equations generated by using Galerkin's technique. A steady state radial flow problem in which transmissivity varies as a linear function of the radius from the well indicates that the accuracy of the numerical scheme may be improved considerably through the use of functional aquifer coefficients. Whenever a system is characterized by sharp changes in permeability or some other parameter, such as those changes that often appear in geologic cross sections, the use of a constant parameter over an element may be advantageous. In the finite element formulation, integration is carried out over each element independently, and a computer code capable of mixing constant and functional coefficients in the same problem is easily generated.

72-73:02F-033

NONLINEAR EQUATION OF UNSTEADY GROUNDWATER FLOW,

Bruch, J. C. Jr.

California University, Santa Barbara, Department of Mechanical Engineering.

Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY3, Paper 9589, p 395-403, March 1973. 5 fig, 7 ref, append.

Descriptors: *Groundwater movement, *Finite element analysis, *Unsteady flow, Water table, Surface-groundwater relationships, Numerical analysis.

Unsteady groundwater movement may be described using a finite element weighted residual process to solve nonlinear partial differential equations. The groundwater in an unconfined aquifer may flow either into or out of a surface reservoir. Rectangular, as well as triangular, finite elements were used in a space-time solution domain. The weighting function was equal to the shape function defining the dependent variable approximation. The results were compared in dimensionless graphs with experimental as well as other numerical data. The finite element method compared favorably with these results and was easily programmed, stable, computationally fast, rapidly convergent, and does not require constant parameters over the entire solution domain.

72-73:02F-034
EXPERIMENTAL AND MATHEMATICAL MODELING OF LIQUID-LIQUID MISCIBLE DISPLACEMENT IN POROUS MEDIA,
Chhatwai, S. S., Cox, R. L., Green, D. W., and Ghandi, B.
Kansas University, Lawrence, Department of Chemical and Petroleum Engineering.
Water Resources Research, Vol. 9, No. 5, p 1369-1377, October 1973. 10 fig, 1 tab, 13 ref.

Descriptors: *Dispersion, *Mixing, *Groundwater movement, Saline water intrusion, Path of pollutants, Diffusion, Numerical analysis, Convection, Mathematical models, Hydraulic models.

When one liquid in a porous medium displaces a second miscible liquid of different density, both gravity effects and dispersion are present at the liquid-liquid interface. Equations describing this process were solved numerically. The method of characteristics numerical solution and a new technique (the centered in distance, centered in time method) were evaluated by direct comparison and by checking against an analytical solution for the case of one-dimensional flow. The solutions were used to simulate saltwater displacement experiments in a two-dimensional laboratory model as a further test.

72-73:02F-035
ANALYTICAL SOLUTIONS TO THE ONE-DIMENSIONAL NONLINEAR DIFFUSION EQUATION FOR FLOW THROUGH POROUS MEDIA,
Moench, A. F.
Geological Survey, Denver, Colorado.
Water Resources Research, Vol. 9, No. 5, p 1378-1384, October 1973. 4 fig, 3 tab, 4 ref.

Descriptors: *Diffusion, *Groundwater movement, *Numerical analysis, *Porous media, Transmissivity, Equations, Mathematical studies, Soil water movement, Saturated flow, Unsaturated flow.

The one-dimensional nonlinear diffusion equation was solved approximately by an extension of the Neumann method for a step input to a semi-infinite medium. The method of solution requires that the region under consideration be divided into an arbitrary number of zones, each zone having known constant diffusivities. The boundaries between zones move at rates that are initially unknown. Two problems were considered: (1) horizontal flow in an aquifer in which the transmissivity and storage coefficients are functions of hydraulic head and (2) horizontal absorption in an unsaturated soil for which the diffusivity is a funtion of moisture content. Computational results compare well with finite difference and other numerical solutions to the same problems. The technique has application to other nonlinear problems of the same type.

72-73:02F-036
EQUATION FOR ONE-DIMENSIONAL VERTICAL FLOW OF GROUNDWATER: 2. VALIDITY RANGE OF THE DIFFUSION EQUATION,
Gambolati, G.
Centro di Ricerca IBM di Venezia (Italy).
Water Resources Research, Vol. 9, No. 5, p 1385-1395, October 1973. 14 fig, 8 ref.

Descriptors: *Groundwater movement, *Consolidation, *Compaction, Land subsidence, Subsidence, Deformation, Diffusion, Equations, Aquifer testing, Porous media, Dispersion, Mathematical studies.

The reliability of the parabolic diffusion equation was investigated by solving the rigorous one-dimensional equation of groundwater flow in deforming soils. The dependence of the hydraulic conductivity on the specific weight of water is included. The grain velocity was expanded first. This expansion leads to a nonlinear integro-differential term. An iterative finite element technique of solution was then developed. The true time-dependent pressure head was compared to the standard one. The entire range of variations for the formation parameters was carefully explored. The usual equation gives satisfactory results in the vast majority of applications. The conditions underlying the approximated theory become critical only when the flow field is to be determined in highly compressible units for strong boundary pressure variations. In this case the solid material movements can no longer be considered small. The pressure head changes are faster than it would appear from the standard solution, and the consolidation process is more rapid than that in the classical Terzaghi's theory.

72-73:02F-037
GALERKIN SOLUTION OF THE INVERSE PROBLEM FOR AQUIFER TRANSMISSIVITY,
Frind, E. O., and Pinder, G. F.
Waterloo University (Ontario), Department of Earth Sciences.
Water Resources Research, Vol. 9, No. 5, p 1397-1410, October 1973. 11 fig, 20 ref.

Descriptors: *Groundwater movement, *Aquifer testing, *Transmissivity, *Finite element analysis, Numerical analysis, Equations, Mathematical models, Flow nets.
Identifiers: *Galerkin method.

The inverse problem in aquifer analysis may be solved by a Galerkin finite element approach. The proposed solution was applied to an inhomogeneous isotropic aquifer for which steady state piezometric head is known and transmissivity is unknown. The condition for existence and uniqueness of a solution is that transmissivity must be known along a line crossed by all streamlines in the flow system. In the Galerkin solution this condition may be stated alternatively in terms of flux, so that knowing the discharge at a well may satisfy the uniqueness requirement. Isoparametric finite elements were used; polynomial shape functions approximated aquifer geometry, hydraulic head, and transmissivity. The flexibility of the isoparametric elements permits using an irregular grid with nodes directly at observation points. The solution is highly sensitive to the degree of approximation in the functional representation of hydraulic head but relatively insensitive to the representation of transmissivity. The finite element solution converges to a unique solution as element size decreases.

72-73:02F-038
TIME SERIES ANALYSIS OF THE HYDROLOGIC REGIMEN OF A GROUNDWATER DISCHARGE AREA,
Jackson, R. E., Gilliland, J. A., and Adamowski, K.
Ottawa University (Ontario), Department of Civil Engineering.
Water Resources Research, Vol. 9, No. 5, p 1411-1419, October 1973. 4 fig, 18 ref.

Descriptors: *Time series analysis, *Groundwater, *Discharge (Water), *Water level fluctuations, Hydrogeology, Variability, Markov processes, Evapotransporation, Statistics, Precipitation (Atmospheric), Climates, Water balance, Hydrograph analysis, *Canada.

Time series analysis was employed to examine climatological and hydrogeological variables associated with a groundwater discharge area in Manitoba, Canada. Daily groundwater evapotranspiration and inflow rate were adequately modeled by a first-order Markov process. Nonrandom fluctuations association with the weather and circulation of the North American summer climate were identified in the time series of mean daily temperature and groundwater evapotransporation; daily precipitation was random. Statistical filtering of the hydrogeological time series showed that two processes were associated with seasonal maximums in the groundwater evapotranspiration series, one due to the propagation of groundwater recharge through the flow system and the other due to climatic effects on the discharge area, in particular, the Lisse effect.

72-73:02F-039
FRICTION FACTOR AND REYNOLDS NUMBER IN POROUS MEDIA FLOW,
Arbhabhirama, A., and Dinoy, A. A.
Asian Institute of Technology, Bangkok (Thailand), Division of Water Science and Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY6, Paper 9784, p 901-911, June 1973. 6 fig, 2 tab, 10 ref, append.

Descriptors: *Porous media, *Fluid friction, *Reynolds number, *Groundwater movement, *Hydraulic radius, Pores, Porosity, Fluid mechanics, Permeability, Hydraulic conductivity.

The concept of hydraulic radius of pore spaces is used to show that the square root of the permeability is the important length parameter in defining the friction factor and Reynolds number in flow through porous media. Hydraulic radius is defined by the Kozeny-Carman theory of hydraulic radius of pore space. Various porous media had different relationships between friction factor and Reynolds number. Experimental results showed a similarity to the Moody diagram used for pipe flow, with the ratio of particle mean diameter to the mean hydraulic radius of pore spaces as the third parameter.

72-73:02F-040

BEHAVIOR OF GROUNDWATER FLOW SUBJECT TO TIME-VARYING RECHARGE,

Tseng, M. T., and Ragan, R. M.
Water Resources Engineers, Inc., Springfield, Virginia.
Water Resources Research, Vol. 9, No. 3, p 734-742, June 1973. 12 fig, 9 ref.

Descriptors: *Groundwater movement, *Recharge, *Equations, *Numerical analysis, Hydraulic models, Water table, Simulation analysis, Mathematical models.
Identifiers: Hele-Shaw models.

The dynamic response of two-dimensional unconfined aquifers subject to localized recharge was studied theoretically. The variations of free surface profiles, discharges, and the flow patters with respect to time in both fully penetrated and partially penetrated aquifer systems are obtained by solving the governing partial differential equations numerically. The method treats the nonlinear free surface boundary as an initial condition, and the overall flow region is solved as a boundary value problem. The numerical results agree with experimental data obtained from Hele-Shaw models. The method may be applied to study the quantitative and qualitative changes in groundwater reservoirs resulting from artificial or natural recharge.

72-73:02F-041

MASS BALANCE AND SPECTRAL ANALYSIS APPLIED TO KARST HYDROLOGIC NETWORKS,

Brown, M. C.
Alberta University, Edmonton, Department of Geography
Water Resources Research, Vol. 9, No. 3, p 749-752, June 1973. 4 fig, 8 ref.

Descriptors: *Water balance, *Karst hydrology, *Statistical methods, Variability, Tracers, Hydrologic budget, Caves, Subsurface flow, Fourier analysis, Frequency analysis, Input-output analysis.
Identifiers: Spectral analysis.

Underground karst drainage systems can be studied by the input-output relations of rivers that flow through them. Tracers enable the quantity of water at a sink that flows to a specific spring, and the fraction of a given spring derived from a sink, to be calculated. When tracer methods are not applicable, cross-covariance and cross-spectral transfer function analysis can be used to examine input-output stage records. These give information about the vadose and/or phreatic nature of the system. An inaccessible karst drainage system in western Alberta has a tracer flow-through time of 80 to 130 hours and a positively skewed cross covariance of 70 to 124 hours; therefore the cave is not completely water filled. Additional unknown inputs are substantiated by a negatively peaking cross covariance.

72-73:02F-042

THE ENVIRONMENTAL TRITIUM CONCENTRATION OF UNDERGROUND WATER AND ITS HYDROLOGICAL INTERPRETATION,

Allison, G. B., and Holmes, J. W.
Commonwealth Scientific and Industrial Research Organization, Glen Osmond (Australia), Division of Soils
Journal of Hydrology, Vol. 19, No. 2, p 131-143, June 1973. 5 fig, 3 tab, 23 ref.

Descriptors: *Tritium, *Groundwater movement, *Water balance, Recharge, Discharge (Water), Tracers, Mixing, Springs, Australia, Model studies.

Models which attempt to correlate the tritium concentration of water taken from aquifers to aquifer parameters are discussed. One model takes into account flow along individual streamlines and relates aquifer parameters to the observed tritium concentration at outflow. For the Gambier Plain unconfined aquifer in southern Australia, the calculated tritium concentration at outflow derived from known aquifer parameters is 0.7 T.U. The measured tritium concentration of several springs at outflow is also 0.7 T.U. Using the complete mixing model and the approximation that samples withdrawn from the aquifer on Eyre Peninsula, South Australia, are fully mixed, the mean annual recharge for the area is estimated at 3 cm/yr.

72-73:02F-043
COMPARISON OF RECHARGE TO GROUNDWATER UNDER PASTURE AND FOREST USING ENVIRONMENTAL TRITIUM,
Allison, G. B., and Hughes, M. W.
Commonwealth Scientific and Industrial Research Organization, Adelaide (Australia), Division of Soils.
Journal of Hydrology, Vol. 17, No. 1-2, p 81-95, October 1972. 3 fig, 2 tab, 20 ref.

Descriptors: *Water balance, *Evapotranspiration, *Infiltration, *Recharge, *Tracers, Tritium, Vegetation effects, *Australia, Pine trees, Soil water, Soil moisture, Sampling.

Recharge to groundwater under pasture and forest at a site on the Gambier Plain, southern Australia, was investigated by using environmental tritium as a tracer. Water from the top 20 cm of the shallow unconfined aquifer was sampled at locations both in pasture and forest during October 1970 and February 1971. For several sites along a groundwater streamline, the mean tritium concentration of groundwater beneath the forest was 1.8 TU, while that under pasture was 12 TU. The mean depths to water were approximately the same for both land covers, being 6.0 m and 5.6 m, respectively. The conclusion is that there is virtually no recharge to groundwater beneath the forest, which contradicts the results of a study of water level fluctuations in the Karstic aquifer of the area.

72-73:02F-044
AN ATTEMPT AT ESTIMATING THE TRANSMISSIBILITIES OF TRAPPEAN AQUIFERS FROM SPECIFIC CAPACITY VALUES,
Adyalkar, P. G., and Mani, V. V. S.
Central Groundwater Board, Nagpur (India).
Journal of Hydrology, Vol. 17, No. 3, p 237-241, November 1972. 2 tab, 9 ref.

Descriptors: *Transmissivity, *Specific capacity, *Hydrogeology, *Groundwater movement, *Thiems equation, Basalts, Aquifer characteristics, Water yield, Drawdown, Aquifer testing.
Identifiers: *India.

Based on Thiem's equilibrium formula, an attempt is made to arrive at an empirical factor for the determination of transmissibility. Multiplying the factor by the specific capacity values of the wells tested gives an average value for T for unconfined water-table aquifer conditions in basalt terrains. The suitability of this method with particular reference to poorly permeable water-table aquifers in Maharashtra in India is discussed.

72-73:02F-045
PERTURBATION ANALYSIS OF THE EQUATION FOR THE TRANSPORT OF DISSOLVED SOLIDS THROUGH POROUS MEDIA, PART III, INFLUENCE OF BOUNDARY CONDITIONS,
Wooding, R. A.
Wisconsin University, Madison, Department of Soil Science.
Journal of Hydrology, Vol. 16, No. 3, p 241-245, July 1972. 1 fig, 5 ref.

Descriptors: *Porous media, *Mass transfer, *Diffusion, *Chemical reactions, *Ion transport, Dispersion, Water chemistry, Permeameters, Chromatography, Solutes, Aqueous solutions.

The properties of solute transport involving firstorder irreversible reaction in a finite column of porous material with unstirred fluid both upstream and downstrean are described in a linearized system. If the effective diffusivity in the column is large compared with that in the unstirred fluid, the Danckwerts boundary conditions are appropriate. This situation is typically found in laboratory columns and chemical reactors. At the upstrean boundary a pseudo-discontinuity in concentration exists, and depends upon the reaction rate and the rate of fluctuation of the input concentration. (The influence of downstream boundary conditions is exponentially small, and is neglected). At the downstream boundary, a small 'back-diffusion' zone exists, and serves to adjust the outlet concentration gradient to zero.

72-73:02F-046
A NEW TECHNIQUE FOR TIME-VARIANT GROUND WATER FLOW ANALYSIS,
Herbert, R., and Zytynski, M.
Journal of Hydrology, Vol. 16, No. 2, p 77-92, June 1972. 13 fig, 6 ref.

Descriptors: *Groundwater movement, *Water level fluctuations, *Drawdown, *Simulation analysis, Drainage effects, Drainage systems, Mathematical models, Seepage, Withdrawal, Permeability, Numerical analysis, Computer programs.

A new numerical method is described which accurately simulates the time-variant movement of the water table in unconfined saturated strata. The method is suitable for use on a digital computer and requires far less storage space and computing time than alternative more complex techniques in regular present day use. The new technique is tested against well-proven alternative methods and proves to be accurate and convenient to use. The new technique is particularly suited to the analysis of the performance of groundwater lowering systems and a suite of programs has been developed based on the new method which has been successfully used as a design aid to many groundwater lowering schemes.

72-73:02F-047
PERTURBATION ANALYSIS OF THE EQUATION FOR THE TRANSPORT OF DISSOLVED SOLIDS THROUGH POROUS MEDIA: II. BASIC NON-LINEAR PROBLEM,
Wooding, R. A.
Wisconsin University, Madison, Department of Soil Science
Journal of Hydrology, Vol. 16, No. 2, p 105-116, June 1972. 3 fig, 7 ref.

Descriptors: *Groundwater movement, *Mass transfer, *Ion transport, *Diffusion, *Mathematical studies, Translocation, Ion exchange, Equilibrium, Leaching, Chemical precipitation, Porous media, Adsorption.

Singular perturbation methods are used to treat analytically the problem of steady one-dimensional flow in a porous column, assuming nonlinear exchange equilibrium and concentration-dependent diffusivity, when the Peclet numer is large. The breakdown of the original problem into a nonlinear outer problem, which is hyperbolic and of first order, and an inner problem which is equivalent to a set of ordinary differential equations, greatly facilitates analysis. The development and movement of concentration discontinuities within the flow is examined via the outer expansion, the first term of which neglects diffusion entirely. The next term gives a first estimate of diffusion effects. Material diffusing towards a discontinuity increases its speed. In the neighborhood of a discontinuity, a state of quasi-equilibrium exists between diffusion and convective effects due to the relative velocity between the characteristics and the discontinuity. The first term of the inner expansion is matched both ahead of and behind the jump with the aid of only one arbitrary function of integration; the second function remains undetermined. At the next order, this function is evaluated as a shift of origin of the inner expansion to match the displacement of the jump due to diffusion. However, at this next order of matching, a new undetermined function appears. Extensions of the method to more general cases of nonlinear, nonequilibrium exchange, and when source terms are present, are discussed briefly.

72-73:02F-048

UNCONFINED AQUIFER AND SLOW DRAINAGE,

Streltsova, T. D.

Birmingham University (England), Department of Civil Engineering.

Journal of Hydrology, Vol. 16, No. 2, p 117-134, June 1972. 6 ref.

Descriptors: *Groundwater movement, *Drawdown, *Water level fluctuations, *Theis equation, Storage coefficient, Water yield, Unsteady flow, Unsaturated flow, Hydrogeology.

Identifiers: *Unconfined aquifers.

One of the features of unsteady free surface flow is the phenomenon of slow draining of water-bearing materials. This phenomenon is usually identified and referred to as delayed yield from storage. By this is understood the slowing of the rate of lowering of the piezometric surface during the early period of pumping for the unsteady radial flow to a pumped well compared to the well-known nonequilibrium Theis theory. However, consideration of the nature of this phenomenon may show an identification to be inexpedient. The slow drainage observed in practice may also be considered as a delayed process of vertical transfer; there is no delayed yield.

72-73:02F-049

THE APPLICATION OF THE AUGER HOLE METHOD IN HOLDERNESS GLACIAL DRIFT,

Bonell, M.

Hull University (England), Department of Geography.

Journal of Hydrology, Vol. 16, No. 2, p 125-146, June 1972. 4 fig, 3 tab, 27 ref.

Descriptors: *Hydraulic conductivity, *Glacial drift, *Groundwater movement, *Aquifer testing, Water yield, Boreholes, Piezometers, Withdrawal, Hydrogeology.

Identifiers: England.

The auger hole method was applied in Holderness glacial drift, England, to determine variations in hydraulic conductivity in the context of a shallow groundwater investigation in a small experimental catchment. The computational methods employed and some details of the practical problems encountered in field measurement are discussed. The results are used in the interpretation of hydrogeological, well hydrograph and drainage phenomena associated with the drift material. The calculated hydraulic conductivity values derived from the Kirkham and Van Bavel and Ernst formulae are compared. The Ernst approximate formula is sufficiently accurate for determination of conductivity within the limited range of pumping test geometries dealt with.

72-73:02F-050
NONSTEADY FLOW IN A RECHARGE WELL-UNCONFINED AQUIFER SYSTEM,
Marino, M. A., and Yeh, W. W. G.
California University, Los Angeles.
Journal of Hydrology, Vol. 16, No. 2, p 159-176, June 1972. 9 fig, 1 tab, 21 ref.

Descriptors: *Unsteady flow, *Injection wells, *Groundwater movement, *Mathematical studies, *Recharge wells, Dupuit-Forchheimer theory, Hydrogeology, Hydraulic conductivity, Artificial recharge, Numerical analysis, Model studies, Mathematical models, Dimensional analysis.

A recharge well-unconfined aquifer system is considered in which the well completely penetrates a homogeneous, isotropic, extensive aquifer. The system is characterized also by nonuniformity of the recharge rate, constancy of the injection head, hydraulic conductivity, and specific yield of the aquifer, and the validity of the Dupuit-Forchheimer assumptions. Dimensional analysis and similarity approximation are used to transform the governing second-order, nonlinear, partial differential equation into a second-order, nonlinear, ordinary differential equation. The differential equation is solved by coupling the fourth-order Runge-Kutta method with the Lagrange interpolation method. The method is inherently stable for any times. Dimensionless graphical solutions of water table profiles at different times are presented for various conditions. A closed-form analytical solution based on the linearized equation is developed that closely approximates the flow system under consideration. Dimensionless graphical solutions for volume and average rate of recharge are presented for conditions commonly encountered in practice. The dimensionless form of the solutions makes possible their application to any well-aquifer system with similar characteristics regardless of the values of the hydraulic properties of the aquifer.

72-73:02F-051
STATISTICAL PROCESSING OF LONG-TERM OBSERVATIONS OF GROUNDWATERS,
Kriz, H.
Ceskoslovenska Akademie Ved, Brno. Geograficky Ustav.
Journal of Hydrology, Vol. 16, No. 1, p 17-37, May 1972. 7 fig, 9 tab, 4 ref.

Descriptors: *Water level fluctuations, *Groundwater, *Data processing, *Statistical methods, Statistics, Water wells, Water balance, Data collections, Hydrologic data.
Identifiers: *Czechoslovakia.

The processing of the seventy-year series (1901-1970) of weekly groundwater levels from observation well No. 12 in the Bohemian Cretaceous Plateau in Moravia illustrates the statistical methods used in Czechoslovakia. The so-called characteristic levels were derived from the weekly groundwater levels for the years 1901-1970. These are groundwater levels that, on the average, are exceeded for a certain number of days in the year and often reported also as a percentage of the total duration of observation. Further characteristics are the average monthly and annual groundwater levels, calculated as arithmetic means from the weekly levels recorded in the individual hydrological years, from which, in turn, the average values for the entire period under study were established. The highest and the lowest annual values were established in addition, as well as the absolute extreme levels for the entire period of 1901-1970. Based on the average annual groundwater levels, the hydrological years 1901-1970 were classified from the viewpoint of their yield rates. Long-term changes in the groundwater storages were studied from the plot of the course of weekly hydrographs. A detailed analysis of the groundwater level variations showed that the change in the storages proceeded, in general, in a regular rhythm.

72-73:02F-052

THE INFLUENCE OF DELAYED DRAINAGE ON DATA FROM PUMPING TESTS IN UNCONFINED AQUIFERS,

Boulton, N. S.
Sheffield University (England), Department of Civil and Structural Engineering.
Journal of Hydrology, Vol. 19, No. 2, p 157-169, June 1973. 2 fig, 9 ref.

Descriptors: *Aquifer testing, *Drawdown, *Water yield, Aquitards, Permeability, Hydrogeology, Anisotropy, Equations.
Identifiers: Delayed yield.

Equations are given for the flow to a pumped well in an aquifer having uniform anisotropy and overlain by a low-permeability aquitard. The water table is assumed to be located in the aquitard. Drainage from the capillary zone above the water table is taken into account. The formation constants may be evaluated by using type curves. A well-known pumping test is reanalyzed, using the given equations. The time-drawdown curves can be explained only by the existence of a low-permeability stratum in the vicinity of the water table. In this example the slow draining of the unsaturated zone above the water table seems to be a significant factor in determining the shape of the time-drawdown curves.

72-73:02F-053

WATER-TABLE FLUCTUATION IN SEMIPERVIOUS STREAM-UNCONFINED AQUIFER SYSTEMS,

Marino, M. A.
California University, Davis.
Journal of Hydrology, Vol. 19, No. 1, p 43-52, May 1973. 4 fig, 7 ref.

Descriptors: *Surface-groundwater relationships, *Water level fluctuations, Recharge, Infiltration, Alluvial channels, Permeability, Drawdown, Equations.

Available expressions which describe the watertable fluctuation in a stream-aquifer system are based primarily on the assumption that the bed of the stream is as permeable as the aquifer it completely cuts through. New analytical expressions were developed, in terms of the head averaged over the depth of saturation, to take into account the semiperviousness of the streambed. The situations considered the finite and semi-infinite aquifer systems in which the water level in the semipervious stream is suddenly lowered below its initial elevation, and suddenly raised above its initial elevation, and maintained constant thereafter. As a by-product, solutions are also obtained for finite and semi-finite aquifer systems in which the bed of the stream is as permeable as the aquifer.

72-73:02F-054
ANALYTIC SOLUTION OF SPATIALLY DISCRETIZED GROUNDWATER FLOW EQUATIONS,
Kuiper, L. K.
Geological Survey, Iowa City, Iowa.
Water Resources Research, Vol. 9, No. 4, p 1094-1097, August 1973. 1 fig,
4 ref.

Descriptors: *Mathematical studies, *Groundwater movement, Numerical analysis, Finite element analysis.

The Galerkin procedure, when it is applied to the equation for horizontal two-dimensional flow of groundwater in a nonhomogeneous isotropic aquifer, generates approximating equations involving square matrices and column matrices. An analytic solution to the matrix equation is given. These methods are compared with the approximate numerical Crank-Nicholson procedure by applying both to a particular problem for which the unknown column matrix has 49 elements. The Crank-Nicholson procedure usually requires less computation time for the confined aquifer case but gives errors for drawdown averaging approximately 10%. The Crank-Nicholson procedure takes considerably more computation time for the unconfined case when elapsed time is long.

72-73:02F-055
ON THE UPTAKE OF TRITIUM BY SOIL WATER AND GROUNDWATER,
Ehhalt, D. H.
National Center for Atmospheric Research, Boulder, Colorado.
Water Resources Research, Vol. 9, No. 4, p 1073-1074, August 1973. 1 tab,
5 ref.

Descriptors: *Tritium, *Tracers, *Soil water, *Groundwater, Soil bacteria, Evaporation, Precipitation (Atmospheric), Oxidation.

Tritiated molecular hydrogen in the atmosphere is oxidized by soil microorganisms and may contribute to the T input into soil with a rate of 5.4 T atom per sq cm per sec. Thus groundwater studies using HTO as a tracer should take this additional T input into account, and measurements of the uptake of HT by local soil, along with the T deposition by rain, may be required to give correct results.

72-73:02F-056
EFFECT OF ACCRETION ON DYNAMICS OF GROUNDWATER BETWEEN TWO CHANNELS,
El Nimr, A.
Slovenska Akademie Vied, Bratislava (Czechoslovakia), Ustav Hydrologie a Hydrauliky.
Water Resources Research, Vol. 9, No. 4, p 1058-1064, August 1973. 6 fig,
5 ref.

Descriptors: *Groundwater movement, *Surface-groundwater relationships, *Mathematical studies, Recharge, Evapotranspiration, Water balance, Infiltration, Evaporation, Seepage.

The effects of infiltration and evaporation on groundwater level and on the amount of seepage to or from channels that bound an unconfined aquifer were studied mathematically. The actual free-surface boundary conditions as well as the exact differential equation were used to obtain the general solution. Three particular cases were studied in detail. In the first, the accretion is considered to be constant, whereas, in the second, it is considered to vary linearly with time. In the third, the accretion occurs only on a part of the aquifer but does not occur on the other parts. For the three cases, the rate of seepage is given in mathematical forms as well as in dimensionless curves. The free-surface profile was also drawn for several cases. A comparison with the solutions based on the Boussinesq equation is presented. These approximate solutions give satisfactory results for shallow aquifers but fail to give reasonably adequate results for relatively thick aquifers. The results of these approximate methods deviate greatly from the exact solutions for small values of time.

72-73:02F-057
MODIFIED MONTE CARLO APPLICATION TO GROUNDWATER MOVEMENT-THE SIMULTANEITY PROCEDURES,
Shih, S. F.
Central and Southern Florida Flood Control District, West Palm Beach.
Water Resources Research, Vol. 9, No. 4, p 1029-1038, August 1973. 4 fig, 6 tab, 1' ref.

Descriptors: *Groundwater movement, *Monte Carlo method, *Mathematical studies, Soil water movement, Statistical methods, Computers, Drawdown, Computer programs.
Identifiers: Simultaneity procedures.

By applying the Monte Carlo methods to problems of water movement in soils, very difficult problems can often be treated easily, and solutions at only a few points in a flow system can be obtained independently. A modified Monte Carlo application, termed the simultaneity procedure, hastens the classical Monte Carlo application. So that the simultaneity procedure can be used more widely, the techniques of a parallel simultaneity procedure and a successive simultaneity procedure were devised. Examples are presented not only for the problems of groundwater movement and Thiessen coefficients but also for the problems of general mathematics. Comparisons of results indicate that the simultaneity procedure has the same accuracy as the classical Monte Carlo method, but the computing time is reduced by approximately 30%-60%.

72-73:02F-058
EQUATION FOR ONE-DIMENSIONAL VERTICAL FLOW OF GROUNDWATER: 1. THE RIGOROUS THEORY,
Gambolati, G.
Centro di Ricerca IBM di Venezia (Italy).
Water Resources Research, Vol. 9, No. 4, p 1022-1028, August 1973. 14 ref.

Descriptors: *Groundwater movement, *Mathematical studies, *Unsteady flow, Porous media, Deformation, Equations, Elastic deformation, Elastic theory, Hydraulic conductivity, Saturated flow, Stress, Strain.

A new mathematical derivation of the one-dimensional flow equation in an elastic, saturated, porous medium is presented. The approach involves the consideration of a fixed elemental volume in fixed coordinates. The derivation is developed by starting from both Lagrangian and Eulerian definitions of the position vector. The Lagrangian and Eulerian formulations prove to be equivalent and provide the same outcome if they are correctly interpreted and consistently applied. The rigorous equation contains an additional nonlinearity resulting from the correct expansion of the partial spatial derivative of the grain velocity. It is also shown that an approach based on a deforming element in fixed coordinates is simple and straightforward, since it does not introduce the grain velocity into the development. However, it needs a particular definition for the compressibility different from the classical one. It is proved that these two compressibilities are not equal; their mathematical link is derived.

72-73:02F-059

CALIBRATION OF DISTRIBUTED PARAMETER GROUNDWATER FLOW MODELS VIEWED AS A MULTIPLE-OBJECTIVE DECISION PROCESS UNDER UNCERTAINTY,

Neuman, S. P.

Volcani Institute of Agricultural Research, Bet-Dagan (Israel), Department of Soil and Water.

Water Resources Research, Vol. 9, No. 4, p 1006-1021, August 1973. 11 fig, 35 ref.

Descriptors: *Groundwater resources, *Flow, *Management, *Decision making, *Linear programming, *Aquifers, Finite element analysis, Optimization, Anisotropy, Systems analysis, Mathematical models, *Risks.
Identifiers: Multiple objectives, Sensitivity analysis.

Due to the deterministic nature of most groundwater flow models, there has been a tendency to overlook the strong element of uncertainty that invariably enters into the problem of parameter identification. Because of this uncertainty, an approach based on the minimization of a single error functional generally does not lead to satisfactory results. A multiple-objective decision process is postulated, accounting for all the available information on the aquifer flow system, as well as the range of environmental conditions under which the system is expected to operate in the future. According to this new approach, a continuous or discrete set of alternative solutions to the identification problem is generated with the aid of mathematical programming techniques, and the decision maker is asked to apply his own value judgment in selecting a particular model structure. The method is illustrated by applying parametric linear programming to a finite element model of steady state flow in a locally anisotropic aquifer. The reliability of each parameter estimate is ascertained using postoptimal sensitivity analysis.

72-73:02F-060

INTEGRODIFFERENTIAL EQUATIONS FOR SYSTEMS OF LEAKY AQUIFERS AND APPLICATIONS: 1. THE NATURE OF APPROXIMATE THEORIES,

Herrera, I., and Rodarte, L.

Universidad Nacional Autonoma de Mexico, Mexico City, Instituto de Geofisica.

Water Resources Research, Vol. 9, No. 4, p 990-1005, August 1973. 4 fig, 27 ref.

Descriptors: *Groundwater movement, *Mathematical studies, *Equations, Aquifer characteristics, Aquicludes, Hydrogeology.
Identifiers: *Leaky aquifers.

The dynamics of leaky aquifers are described by a system of integrodifferential equations. Alternative expressions for the memory functions are obtained, and it is shown that approximate theories of leaky aquifers correspond to several ways of approximating the memory functions. By means of analysis of these functions in the time domain it is possible to achieve a better understanding of the nature of these approximations as well as to foresee the possibility of their application to new situations. These types of results constitute important steps toward making the integrodifferential equations a powerful method of analysis of the very complex situations arising in the study of actual leaky aquifer systems. They can also be used to construct improved, simplified methods for numerical computation.

72-73:02F-061
CAPILLARY PROPERTIES OF SOILS-INFLUENCE UPON SPECIFIC YIELD,
Duke, H. R.
United States Department of Agriculture, Agricultural Research Service, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 688-691, July-August, 1972. 6 fig, 2 tab, 9 ref.

Descriptors: *Specific yield, *Capillary action, Subsurface drainage, Groundwater, Groundwater availability, Retention, Safe yield, Dug wells.

The discussion presented indicates that capillary properties of a porous medium are important hydrologic parameters for situations of groundwater flow in which capillary effects are generally considered negligible. Although the utility of the specific yield concept has been proved many times under practical field conditions, the hydrologist should be aware of the limitations of the data he has collected. Of particular importance is an awareness of the errors introduced by using specific yields determined under one set of experimental conditions to predict ground water movement under completely different conditions. The primary purpose has been to show that specific yield as classically defined is not a unique property of the porous medium in which it is measured.

72-73:02F-062
COMPARISON OF STRENGTH TEST METHODS FOR CORRUGATED PLASTIC DRAINAGE TUBING,
Soribe, F. I., Fouss, J. L., and Schwab, G. O.
Ohio State University, Agricultural Engineering Department, Columbus.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 445-447, May-June, 1972. 8 fig, 8 ref.

Descriptors: *Plastic deformation, *Plastic pipes, Closed conduits, Tile drains, Tiles, Subsurface drains, Pipes.

The sand box and parallel plate methods for measuring the load deflection of corrugated plastic drainage tile were evaluated. Twelve-inch lengths of unslotted plastic tubing at a temperature of 72 degrees F. and 50% relative humidity were tested using both methods. Deflection of the tubing was not allowed to exceed 5%. The load is linearly related to the deformation for deflections less than 5% in both test methods. Both methods give similarly accurate results. The parallel plate method is preferred because it is much faster to perform.

72-73:02F-063
HYDRAULIC ROUGHNESS OF CORRUGATED PLASTIC TUBING,
Irwin, R.W., and Tsang, G.
Guelph University, Guelph, Ontario, Canada.
Transactions of the American Society of Agricultural Engineers, Vol 15, No 2, p 290-291, 295, March-April, 1972. 3 fig, 1 tab, 10 ref.
(See 72-73:08B-007)

72-73:02F-064
WATER-MANAGEMENT PROBLEMS RELATED TO GROUNDWATER RIGHTS IN THE SOUTHWEST,
Thomas, H.E.
United States Geological Survey, Menlow Park, California.
Water Resources Bulletin, Vol 8, No 1, p 110-117, February 1972. 27 ref.
(See 72-73:04B-020)

72-73:02F-065
ROLE OF MODELS IN GROUNDWATER MANAGEMENT,
Weber, E.M., and Hassan, A.A.
California Department of Water Resources, Sacramento.
Water Resources Bulletin, Vol 8, No 1, p 198-206, February 1972. 3 fig, 1 tab.
(See 72-73:02A-008)

72-73:02F-066
MODELLING A GROUNDWATER AQUIFER IN THE GRAND PRAIRIE OF ARKANSAS,
Griffis, C.L.
Arkansas University, Agricultural Engineering Department, Fayetteville.
Transactions of the American Society of Agricultural Engineers, Vol 15, No 2, p 261-263, March-April, 1972. 6 fig, 5 ref.

Descriptors: *Groundwater, *Computer models, *Mathematical models, Aquifer management, Groundwater recharge, Recharge wells, Artificial recharge, Water yield, Surface-groundwater relationships, Aquifers.

Most of the irrigation water for the Grand Prairie of Arkansas comes from the Quaternary aquifer lying beneath the area. Constant pumping has lowered the water table and shortened the water supply. A model was developed to investigate the possibility of artificial recharging of the aquifer. The area was divided into sections of one square mile. The flow equations were then solved for each section. Various methods of recharge were then evaluated using the model. Recharge wells were found to provide the best solution.

72-73:02F-067
GROUNDWATER MANAGEMENT,
Peters, H.J.
California Department of Water Resources, Sacramento.
Water Resources Bulletin, Vol 8, No 1, p 188-197, February 1972. 1 fig.
(See 72-73:02A-010)

72-73:02F-068
TENSIOMETER USE IN SHALLOW GROUND-WATER STUDIES,
Richards, S.J., Willardson, L.S., Davis, S., and Spencer, J.R.
Soil Physicist, Riverside California
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 99, IR4, p 457-464, December 1973. 7 fig, 7 ref.

Descriptors: *Drainage, *Groundwater, Measurement, Piezometers, Pore water, Pore pressure, Seepage, Tensiometers, Water table, Wells.

Tensiometers installed with a ground surface or other reference can be used to determine groundwater equipotentials and the position of the water table in the field. Tensiometer determined water tables were roughly comparable to those measured with perforated wells in a sprinkler irrigated Coachella fine sandy soil. Water differences depended on the flow conditions and proximity of the tensiometers to a drain. Shallow groundwater equipotentials can be determined above and below the water table with a tensiometer system.

72-73:02F-069
APPROXIMATE SOLUTION FOR UNCONFINED SEEPAGE,
Desai, C.S.
United States Army Engineer Division, Waterways Experiment Station, Vicksburg, Mississippi.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 99, No IR1, p 71-87, March 1973. 12 fig, 24 ref.

Descriptors: *Drainage, *Finite element analysis, *Free surfaces, Interfaces, Irrigation, Numerical analysis, Seepage, Transition flow.

An approximate solution procedure using the finite element method is developed for one-dimensional unsteady free surface seepage. The numerical results are compared with experiments on a viscous flow model and with analogue solutions. Satirfactory correlation is obtained between the numerical and experimental results. Results from the proposed procedure based on one-dimensional formulation are compared with those from two- and three-dimensional formulations. Numerical properties of the proposed procedure with respect to timewise and spatial discretizations, magnitudes of permeability, and use of higher order approximating functions are analyzed. The proposed solution can provide satisfactory and economical solutions for many practical problems that can be idealized as one-dimensional.

72-73:02F-070
DETERMINATION OF EQUIVALENT RADII FOR RECTANGULAR DRAINS,
Warrick, A.W.
Arizona University. Tucson.
Soil Science Society of America Proceedings, Vol 37, No 5, p 809-811, September-October 1973. 2 fig, 8 ref.
(See 72-73:02G-139)

72-73:02F-071
A FLOW PATH GROUND WATER SAMPLER,
Willardson, L.S., Meek, B.D., and Huber, M.J.
Imperial Valley Conservation Research Center, Brawley, California.
Soil Science Society of America Proceedings, Vol 36, No 6, p 965-966, November-December 1972. 4 fig.

Descriptors: *Drainage, *Tile drainage, Salinity, Groundwater, Sampling,

A sampling system is described that enables collection of water samples from different flow paths in the ground-water system around a tile drain. The sampler can be installed as a regular part of a tile drainage system.

72-73:02F-072
VALIDITY OF DUPUIT-FORCHHEIMER EQUATION,
Murray, W.A., and Monkmeyer, P.L.
Lehigh University, Bethlehem, Pennsymvania. Department of Civil Engineering.
Society of Civil Engineers, Vol 99, No HY9, Paper 9997, p 1573-1583, September 1973. 4 fig, 16 ref, append.

Descriptors: *Dupuit-Forchheimer theory, *Groundwater movement, *Slopes, Equations, Drawdown, Water yield, Mathematical studies, Aquifers.

The Dupuit-Forchheimer equation describing unconfined groundwater flow is limited by the underlying assumptions inherent in its derivation. A validity criteriod developed from an analysis of the exact equations of motion shows that, in general. the Dupuit-Forchheimer equation describes a rising water table more accurately than a falling one. In the steady state the criterion reduces to a simple restriction on the free surface slope. For unsteady flow, the criterion involved both the free surface slope and the rate of change of the free surface position. The free surface slope must be no greater than 1:10

if results are expected to be within 1% of exact. More accurate results should be obtained by using data from either a recharging well or the recovery period after pump shutdown rather than drawdown data.

72-73:02F-073
AGRICULTURAL DEMAND FOR WATER IN THE PECOS RIVER BASIN: AN ADDENDUM,
Gisser, M.
New Mexico University, Department of Economics, Albuquerque.
Water Resources Research Vol 9, No 5, p 1429-1432, October 1973. 4 tab, 2 ref.

Descriptors: *Water utilization, *Agriculture, Groundwater recharge, Groundwater availability, Groundwater mining.

A study that deals with importing water to the Pecos River basin and using this water without artificial recharging is compared with another study that deals with the problem of recharging imported water into the aquifer. The sensitivity of the demand for water function to changes in salinity constraints is explored and the possibility of reducing natural discharge of water by lowering the evaporation rate of salt cedars is investigated.

72-73:02F-074
A GALERKIN-FINITE ELEMENT SIMULATION OF GROUNDWATER CONTAMINATION ON LONG ISLAND, NEW YORK.
Pinder, G.F.
Princeton University, Department of Civil and Geological Engineering, Princeton, New Jersey.
Water Resources Research, Vol 9, No 6, p 1657-1669, December 1973. 7 fig, 18 ref.

Descriptors: *Groundwater, *Pollutants, *Soil physics, Water pollution sources, Water quality control, Chromium.

The Galerkin method of approximation in conjunction with the finite element method of analysis may be used to simulate the movement of groundwater contaminants. In solving the groundwater flow and mass transport equations this approach allows a functional representation of the dispersion tensor, transmissivity tensor, and fluid velocity, as well as an accurate representation of boundaries of irregular geometry. A field application of the method to chromium contamination on Long Island, New York, shows that accurate simulations can be obtained by using the Galerkin-finite element approach.

72-73:02F-075
FLOW TOWARD PERIODIC TILE DRAINS,
Gyuk, I., Soriano, A., and Karadi, G.M.
Wisconsin University, School of Architecture, Milwaukee
Journal of Hydrology, Vol 19, No 2, p 113-129, June 1973. 9 fig, 3 ref.

Descriptors: *Drainage, *Groundwater, Tile drainage, Subsurface drainage, Drainage practices, Drainage systems, Soil water movement, Drainage engineering.

The method of conformal mapping is applied to the analysis of transient flow toward parallel periodic drains in a semi-infinite aquifer taking into consideration the non-linear boundary conditions on the free surface. The mapping function is expressed as a power series in time and the seepage domain is mapped onto a domain of an auxiliary complex variable. Mapping is performed in such a manner that the free surface will always remain the real axis. Calculations are carried out for different ratios of drain depth to drain spacing using various drain diameter to depth ratios.

72-73:02F-076
SOIL-SUCTION MEASUREMENTS FOR EVALUATION OF VERTICAL WATER FLOW AT GREATER DEPTHS WITH A PRESSURE TRANSDUCER TENSIOMETER,
Strebel, O., Renger, M., and Giesel, W.

Budensanstalt fur Bodenforschung und Niedersachsisches Landesamt fur Bodenforschung, Hannover, Germany.
Journal of Hydrology, Vol 18, No 3/4, p 367-370, March 1973. 2 fig, 6 ref.

Descriptors: *Soil water, *Soil moisture, *Tensiometers, Moisture tension, Soil water movement, Available water.

Periodic suction measurements at greater depths can be carried out in cased boreholes using a temporarily installed pressure transducer tensiometer. The time needed to reach constant suction values depends upon the tensiometer prestressing and the soil suction, and amounts to about 15 min. to 2 1/2 hours according to general experience. With this technique, requiring relatively low expense for instruments, the hydraulic gradient and - combined with corresponding hydraulic conductivity values - the vertical water flow can be determined at depths up to about 10 m.

72-73:02F-077
HAMMAT GADER (ISREAL): GEOCHEMISTRY OF A MIXED THERMAL SPRING COMPLEX,
Mazor, E., Kaufman, A., and Carmi, I.
The Weizmann Institute of Science, Rehovot, Israel.
Journal of Hydrology, Vol 18, No 3/4, p 289-303, March 1973. 8 fig, 7 tab, 14 ref.

Descriptors: *Groundwater, *Salinity, *Springs, Thermal springs, Cold springs, Mineral water, Spring waters, Water types.

A complex of four spring groups has been studied. The temperature and concentrations of dissolved ions reveal the springs to be mixtures of two types of water whose characteristics were deduced by extrapolation. The hot end member is enriched in He4, Ra226, and nitrogen, flushed from the hot aquifer rocks. The Ne, Ar, Kr, and Xe have atmospheric isotopic compositions and occur in relative elemental abundances similar to those dissolved in air-saturated water. This indicates that both water end members originated from rain water that equilibrated with air and infiltrated into the ground. The Ar, Kr, and Xe concentrations revealed that both water types were formed from rains that entered the ground at "paleotemperatures" of 19 ± 3C. The tritium and C14 values indicate the true hot end member to have an age older than 117,000 years whereas the true cold end member has an age of 12,000 ± 1,500 years. The cold spring D is mixed with about 3% post-nuclear-tests rain water.

72-73:02F-078
EXPERIMENTS IN TRACING UNDERGROUND WATERS IN LIMESTONES,
Atkinson, T.C., Smith, D.I., Lavis, J.J., and Whitaker, R.J.
Bristol University (England) Department of Geography.
Journal of Hydrology, Vol 19, No 4, p 323-349, August 1973. 15 fig, 2 tab, 32 ref.

Descriptors: *Tracers, *Groundwater movement, *Karst hydrology, Limestones, Dye releases, Karst, Hydrogeology, Surface-groundwater relationships.
Identifiers: *England.

Two experiments were conducted in the Carboniferous Limestone aquifer of the Mendip Hills, Somerset, to compare the relative merits of differing groundwater tracers. The tracers employed were lithium acetate, polyethylene powder, Lycopodium spores, and the fluorescent dye Pyranine; all were introduced into the aquifer at stream sinks. Lithium acetate and polyethylene powder were totally unsuccessful. The rates of travel of the fluorescent dye and Lycopodium spores were very similar. Absolute concentration for dye can be determined using a field continuous flow fluorometer. The quantitative dye concentration data can be used with simultaneous measurements of discharge at the spring to deduce the flow geometry of the system; the input, tributary, distributary and maximum discharges in the system; and the volume of the underground conduits. Exchange takes place between the flooded conduit and the surrounding fissured bedrock in a manner analogous to bank storage in rivers flowing on alluvium.

72-73:02F-079

UNSTEADY FLOW TO BOTTOM DRAIN IN BOUNDED AQUIFER,

Krizek, R.J., Soriano, A., and Gyuk, I.
Northwestern University, Tkchnological Institute, Evanston, Illinois.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 99, No IR2, p 169-182, June 1973. 6 fig, 11 ref.

Descriptors: *Groundwater, *Aquifers, *Aquifer characteristics, Drainage, Tile drains, Irrigation, Seepage, Transition flow.
Identifiers: Conformal mapping, Complex variables.

The problem of transient seepage toward a drain at the bottom of a homogeneous, isotropic aquifer is presented. The dependent variables are the position of the free surface, the flow rate, and the pore pressure distribution around the drain, and these are determined as functions of time for various depths of drainage and drain sizes; the characteristics of the aquifer are specified in terms of its coefficient of permeability and its effective porosity. The mathematical statement of this problem yields to a time-dependent potential field within a strip domain bounded by the impervious bottom, the moving free surface, and a small semicircular contour representing the drain. To overcome the difficulty of a moving boundary, a conformal mapping technique is used to transform the problem into a new plane in which the free surface remains straight and fixed. The solution of the problem is found to the third order of time, and an upper bound is given to limit the range within which it is valid.

72-73:02F-080

EVALUATION OF WATER FLUX ABOVE A DEEP WATER TABLE USING THERMOCOUPLE PSYCHOMETERS,

Enfield, C.G., Hsieh, J.J.C., and Warrick, A.W.
Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma.
Soil Science Society of America Proceedings, Vol 37, No 6, p 968-970, November-December, 1973. 3 fig, 12 ref.

Descriptors: *Groundwater, *Soil water, Potential flow, Recharge, Unsaturated flow.

Deep water flow was evaluated in a Washington desert environment using hydraulic conductivity and potential gradients. Thermocouple psychrometers and temperature transducers were installed to depths of 94 m. in the soil profile and used to measure the potential gradients. The hydraulic conductivity was calculated using a modified Millington and Quirk equation and the soil moisture characteristic curve. The thermal fluid diffusivity was calculated and used to estimate flow induced by thermal gradients. Under the conditions studied, a more refined analysis of the thermally induced flow is required to give a definite answer as to the direction of flow. It was concluded, that is flow existed at this location, it was less than 1 cm/year.

72-73:02F-081

ON THE LEAKAGE ASSUMPTION APPLIED TO EQUATIONS OF GROUNDWATER FLOW,

Streltsova, T.D.
Birmingham University, Civil Engineering Department, Birmingham, Great Britain.
Journal of Hydrology, Vol 20, No 3, p 237-253, November 1973. 3 fig, 24 ref.

Descriptors: *Groundwater, *Computer models, *Mathematical models, Confined water, Aquifers, Groundwater potential, Soil water.

The behavior and the delayed response of flow to a well in an unconfined aquifer is considered on the basis of recognition of the variable vertical movement of flow inherent in unconfined flow. The effect of elastic storage is taken into account. The typical S-shaped form of the characteristic time--drawdown curve of an unconfined aquifer is analyzed. A procedure for determining the unconfined parameters is described. It is shown that the vertical components of flow are a significant factor in the delayed response of an unconfined aquifer while the contribution of the unsaturated zone is essentially subordinate. An equation including allowance for the drainage from the unsaturated zone is derived.

72-73:02F-082
A DISCRETE SPACE CONTINUOUS TIME MODELING APPRAOCH TO NONSTEADY FLOW IN A LEAKY AQUIFER SYSTEM OF FINITE CONFIGURATION,
Marino, M.A., and Yeh, W.W.G.
California University, Davis.
Journal of Hydrology, Vol 20, No 3, p 255-266, November 1973. 5 fig, 11 ref.

Descriptors: *Groundwater, *Computer models, *Mathematical models, Confined water, Aquifers, Groundwater potential, Soil water.

Existing analytical procedures for nonsteady flow in a leaky confined aquifer assume that the aquifer system is realy infinite. A technique is presented that treats a leaky confined aquifer system of finite configuration. By means of a discrete space continuous time (DSCT) modeling approach, the partial differential equation governing the flow system is transformed into a set of ordinary differential equations that can be easily integrated numerically on a high speed digital computer using available scientific subroutines. The finite difference formulation is in effect an explicit scheme. A criterion is developed for which the scheme is computationally stable. A numerical example is presented.

72-73:02F-083
GROUNDWATER POLLUTION AND CONSERVATION,
Environmental Science and Technology, Vol 6, No 3, p 213-215, March 1972. 2 fig.

Descriptors: *Groundwater, *Aquifers, *Aquifer systems, Areal hydrogeology Bodies of water, Dug wells, Groundwater availability, Groundwater resources, Soil water.

A general overview of the groundwater reserves in the United States is presented. Possible sources of contamination is outlined. Suggested programs for regulation of groundwater use are discusses. A map showing the known aquifers in the United States that are capable of yielding wells of 50 gpm or more at salinity levels not higher than 2000 ppm was developed.

72-73:02F-084
INJECTION WELLS POSE A POTENTIAL THREAT,
Environmental Science and Technology, Vol 6, No 2, p 120-122, February 1972. 3 fig.

Descriptors: *Groundwater, *Waste disposal wells, Injection wells, Underground waste disposal, Waste disposal, Waste storage, Waste water disposal.

The field of injection wells for waste disposal is explored. There are literally tens of thousands of wells now being used. There are no records of areas where wastes have already been injected. There is a need for further research to develop the needed technology. Since the effects of pollutants in the groundwater system are both slow to appear and correct, great care should be taken to minimize the risks.

Section VII

WATER CYCLE

WATER IN SOILS (GROUP 02G)

72-73:02G-001
CATION ADSORPTION IN ONE-DIMENSIONAL FLOW THROUGH SOILS: A NUMERICAL SOLUTION,
Lai, S.H., and Jurinak, J.J.
Utah State University, Logan. Department of Soil Science and Biometeorology.
Water Resources Research, Vol 8, No 1, p 99-107, February 1972. 9 fig, 1 tab, 15 ref.

Descriptors: *Cation adsorption,*Numerical analysis, *Soil chemistry, Dispersion, Adsorption, Soil water movement, Clays, Ion exchange.

A numerical method was developed to solve the problem of the cation adsorption operation involving a general nonlinear exchange function. The method may be applied to solve the cation adsorption operation involving five different types of exchange functions. The adsorption of a cation depends on the equilibrium behavior of the counterions, which is defined by the exchange function. The separation factor is used as an index of the adsorption operation.

72-73:02G-002
SPECIFIC CONDUCTANCE MODEL FOR NATURAL WATERS AND SOIL SOLUTIONS OF LIMITED SALINITY LEVELS,
Tanji, K.K., and Biggar, J.W.
California University, Davis, Department of Water Science and Engineering.
Water Resources Research, Vol 8, No 1, p 145-153, February 1972. 4 tab, 13 ref.

Descriptors: *Conductivity, *Soil water, *Aqueous solutions, *Saline water, *Electrical conductance, Solutes, Water chemistry, Water properties, Ions, Water temperature.
Identifiers: *Specific conductance

The specific conductance of waters and soil solutions may be estimated with a simplified multicomponent conductance model. This model considers solute composition and concentration and a lumped coefficient for ionic interactions, retardation effects, and ion association. The effect of temperature on specific conductance is also considered. Comparison of measured and calculated specific conductances indicate that this empirical model is most applicable to waters and soil solutions with limited salinity levels. Conductance is approximately related to the total soluble cations and the total dissolved salts.

72-73:02G-003
ON THE TENSOR CONCEPT OF UNSATURATED ANISOTROPIC HYDRAULIC CONDUCTIVITY,
Cisler, J.
Technical University of Prague (Czechoslavakia). Lab. of Soil Science.
Water Resources Research, Vol 8, No 2, p 525-528, April 1972. 1 fig, 7 ref.

Descriptors: *Hydrualic conductivity, *Soil water movement, *Anisotropy, *Mathematical studies, Seepage, Groundwater movement, Physical properties, Darcy's Law.
Identifiers: Hydraulic conductivity tensor.

Unsaturated hydraulic conductivity can be regarded as a second order tensor, the coefficients of which depend on soil moisture suction or soil moisture content. General equations for the three-dimensional anisotropic unsaturated flow of water in porous media must involve nine coefficients of the hydraulic conductivity tensor, all of which are, in general, nonzero. Equations for horizontal anisotropic unsaturated flow can be reduced to an orthotropic form with principal hydraulic conductivities, provided the principal axes of the conductivity tensor do not rotate when the moisture content or the soil moisture suction changes. This condition is fulfilled only for a constant ratio of hydraulic conductivities in different directions that is independent of the soil moisture suction or soil moisture content. In this case the flow velocity is given by the simple Darcy type equation without the cross coefficients of hydraulic conductivity. A simple experimental method is proposed to determine the diagonal and cross coefficients of the hydraulic conductivity as functions of the soil moisture suction for horizontal unsaturated steady flow in anisotropic porous media.

72-73:02G-004
DRAINAGE IN SOILS WITH INITIAL GRADIENT,
Valsangkar, A.J., and Subramanya, K.
Indian Inst. of Tech., Kanpur. Department of Civil Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 98, No IR2, p 309-315, June 1972. 5 fig, 11 ref.

Descriptors: *Trenches, *Non-Newtonian flow, *Groundwater movement, *Flow characteristics, *Soil water movement, Drainage water, Dupuit-Forcheimer theory, Confined water, Hydraulic gradient, Hydraulic models, Theoretical analysis.
Identifiers: *Unconfined flow, *Initial gradient.

Seepage through clayey and loamy soils is a common problem in the field and drainage engineering. Like many non-Newtonian fluids, seepage through such soils is initiated only when the hydraulic gradient exceeds a certain value called the initial gradient. Consequences of this type of non-Darcy behavior are of potential interest in several disciplines. In drainage problems nonrecognition of the initial gradient will result in inefficient layout of the drains. Assuming the Dupuit-Forcheimer assumptions to be valid, a general solution for unconfined flow into a trench has been derived. The importance of the initial gradient in affecting the spacing of the trench and discharge reduction, is emphasized. In confined flow, the presence of the initial gradient reduces the effective head.

72-73:02G-005
MOVING WATER TABLES IN TILE-DRAINED SOILS,
Awan, N.M., and O'Donnell, T.
West Pakistan University of Encingeering and Technology, Lahore. Department of Civil Engineering.
American Society of Civil Engineers, Journal of the Irrigation and Drainage Division, Vol 98, No IR3, p 459-477, September 1972. 9 fig, 17 ref.

Descriptors: *Water level fluctuations, *Hydraulic models, *Water table, *Tile drainage, Model studies, Drawdown, Steady flow, Subsurface drainage, Tile drains, Groundwater movement,
Identifiers: *Hele-Shaw models.

A Hele-Shaw analogy of the tile drainage problem was used to provide data on moving water table characteristics. The experimental data for water table recession following complete cessation of recharge are presented in comparison with five analytical solutions and two numerical solutions. Experimental data on rising water tables following sudden commencement of recharge are also presented. The drainage variables whose effects on the moving water table are reported are: (1) The initial or final steady-state mid-drain water table height; (2) the depth of the impermeable bed below the drain axis; and (3) the drain size. Drainage characteristics are virtually independent of the depth of the impermeable bed below the drain axis once that depth is one-eight or more of the spacing between drains, regardless of the initial steadystate water table height. For given values of an appropriate dimensionless time parameter, the proportional amount of rise increases with increasing ym/d, but at a progressively diminishing rate.

72-73:02G-006
MODELING INFILTRATION DURING A STEADY RAIN,
Mein, R.G., and Larson, C.L.
Minnesota University, St. Paul. Department of Agricultural Engineering.
Water Resources Research, Vol 9, No 2, p 384-394, April 1973. 10 fig, 2 tab, 23 ref.

Descriptors: *Infiltration, *Rainfall-runoff relationships, *Mathematical models, Wetting, Soil water movement, Rainfall intensity, Hydraulic conductivity.

A simple two-stage model describes infiltration under a constant intensity rainfall into a homogeneous soil with uniform initial moisture content. The first stage predicts the volume of infiltration to the moment at which surface ponding begins. The second stage, which is the Green-Ampt model modified for the infiltration prior to surface saturation, describes the subsequent infiltration behavior. A method is given for estimating the mean suction of the wetting front. Comparison of the model predictions with experimental data and numerical solutions of the Richards equation for several soil types shows excellent agreement.

72-73:02G-007
PERTURBATION ANALYSIS OF TWO-PHASE INFILTRATION,
Noblanc, A., and Morel-Seytoux, H.J.
Colorado State University, Fort Collins, Department of Civil Engineering.
Proceedings, American Society of Civil Engineers, Journal of the Hydraulics Division, Vol 98, No HY9, Paper 9186, p 1527-1541, September 1972. 10 fig, 5 ref, append.

Descriptors: *Infiltration, *Soil water movement, *Unsaturated flow, *Capillary action, Analytical techniques, Percolation, Permeability, Hydraulic conductivity, Capillary conductivity.
Identifiers: *Perturbation analysis, *Multiphase flow.

An analytical treatment for the problem of one-dimensional infiltration into a homogeneous porous medium is presented. Movement of both the air phase and the water phase and compressibility of the air are considered. The procedure assumes that some capillary terms can be neglected in the saturation equation, whereas all capillary terms are retained in an integral equation for the unknown total flow. Infiltration rate curves are obtained for a number of situations involving different boundary or initial conditions or both. Comparisons are made with results of an earlier and simpler procedure, confirming the validity of the simpler procedure. It is recommended that the traditional unsaturated flow equation be abandoned in favor of the two-phase flow approach.

72-73:02G-008
A TECHNIQUE USING POROUS CUPS FOR WATER SAMPLING AT ANY DEPTH IN THE UNSATURATED ZONE,
Wood, W.W.
Geological Survey, Lubbock, Texas.
Water Resources Research, Vol 9, No 2, p 486-488, April 1973. 2 fig, 2 ref.

Descriptors: *Sampling, *Soil water, *Soil moisture, *Lysimeters, *Zone of aeration, Instrumentation, Unsaturated flow.
Identifiers: *Suction lysimeters, *Soil water sampling, Porous cup lysimeters.

Porous cups or suction lysimeters provide a simple and direct method for collecting water samples in the unsaturated zone. A new procedure is described in which a check valve is placed in the sample collection assembly. This construction permits complete collection at any depth without the loss of samples. A detailed description of construction and operation illustrates the advancement over previous designs.

72-73:02G-009
NUMERICAL TREATMENT OF THE UNSATURATED WATER FLOW EQUATION: COMPARISON OF EXPERIMENTAL AND COMPUTED RESULTS,
Giesel, W., Renger, M., and Strebel, O.
Niedersaechsisches Landesamt fuer Bodenforschung, Hanover (West Germany).
Water Resources Research, Vol 9, No 1, p 174-177, February 1973. 4 fig, 5 ref.

Descriptors: *Infiltration, *Unsaturated flow, *Numerical analysis, *Equation, Infiltrometers, Laboratory tests, Hysteresis, Soil water movement.

A numerical solution of the differential equation governing the unsaturated vertical water flow in soils was applied to results of infiltration and redistribution experiments carried out in a sand column. The boundary condition at the bottom was determined through the fact that during the first 3-4 hours all the water accumulated in the soil. The computed and measured water contents and water suctions agree well. Hysteresis is taken into consideration in this numerical treatment. The agreement between experimental and numerical results is satisfying.

72-73:02G-010
MODIFIED APPROACH TO CAPILLARY HYSTERESIS BASED ON A SIMILARITY HYPOTHESIS,
Mualem, Y.
Technion-Israel Inst. of Technology, Haifa. Department of Civil Engineering.
Water Resources Research, Vol 9, No 5, p 1324-1331, October 1973. 8 fig, 23 ref.

Descriptors: *Unsaturated flow, *Capillary action, *Hysteresis, Soil water movement, Wetting, Drying, Capillary conductivity, Pores.
Identifiers: Capillary hysteresis.

A simplified approach to the capillary hysteresis phenomenon is based on a similarity hypothesis. A simple method predicts the relationships between the capillary head and the water content within the hysteretic loop. Only the boundary curves of the main loop are required in order to derive analytically the scanning curbes. The realiability of the proposed model is demonstrated by a comparison of the predicted scanning curves with measured ones. The computed results are often in more satisfactory agreement with experiments than those obtained with the use of the general Neel-Everett model.

72-73:02G-011
MOISTURE VARIATION AT THE SOIL SURFACE AND THE ADVANCE OF THE WETTING FRONT DURING INFILTRATION AT CONSTANT FLUX,
Braester, C.
Technion-Israel Inst. of Tech. Haifa. Department of Civil Engineering.
Water Resources Research, Vol 9, No 3, p 687-694, June 1973. 4 fig, 2 tab, 16 ref.

Descriptors: *Infiltration, *Soil water movement, *Numerical analysis, *Equations, Finite element analysis, Unsaturated flow, Hydraulic conductivity, Saturated flow, Diffusivity, Wetting.

The problem of infiltration at constant flux at the soil surface was solved approximately in an analytical closed form. The solutions are valuable when dealing with sprinkler irrigation or infiltration of rain. Infiltration into a semi-infinite soil column and infiltration into a soil column of finite length with a constant water table were considered. Analytical and numerical results were compared. The analytical solutions provide a satisfactory prediction of the moisture content at the soil surface and of the advance of the wetting front. The results are presented in a dimensionless form.

72-73:02G-012
RELATIVE LEACHING POTENTIALS ESTIMATED FROM HYDROLOGIC SOIL GROUPS,
England, C.B.
Agricultural Research Service, Beltsville, Maryland. Hydrograph Lab.
Water Resources Bulletin, Vol 9, No 3, p 590-597, June 1973. 2 fig, 2 tab, 7 ref

Descriptors: *Leaching, *Soil water movement, *Soil groups, Recharge, Groundwater movement, Infiltration, Soil properties, Path of pollutants, Percolation.

Leaching of soils with water can be both beneficial and hazardous at the same time, by removing salts harmful to plants and contributing dissolved substances to groundwater. The leaching potential of a given soil is difficult to assess, even with complex instrumentation. The final infiltration rates associated with the Hydrologic Soil Groups used by the USDA Soil Conservation Service in watershed planning may provide a useful guide in estimating quantities of leaching water moving through soil profiles.

72-73:02G-013
HORIZONTAL SOIL-WATER INTAKE THROUGH A THIN ZONE OF REDUCED PERMEABILITY,
Ahuja, L.R., and Swartzendruber, D.
Purdue University, Lafayette, Indiana.
Journal of Hydrology, Vol 19, No 1, p 71-89, May 1973. 8 fig, 29 ref.

Descriptors: *Infiltration, *Percolation, *Soil water movement, *Unsaturated flow, Saturated flow, Numerical analysis, Hydraulic conductivity, Wetting.
Identifiers: *Horizontal infiltration.

One-dimensional, horizontal soil-water absorption through a thin zone of constant nonzero hydraulic resistance was examined theoretically as well as a similarity reduction of the problem for early to intermediate times. The flow equations were transformed by introducing a dimensionless parameter which enables the solution for any value of thin-zone resistance to be obtained from the solution for a given known thin-zone resistance. At the inlet boundary between the thin zone and the soil column, the soil-water content increases with time to approach the saturated value. The cumulative absorption of water by the soil column increases more than proportionally with the square root of time for early and intermediate times, and approached a square-root-or-time proportionality at large times. For both the soil-water content at the inlet boundary and the cumulative water absorption by the soil column, simple expressions arise from the similarity-reduction analysis, which is based on specific functional forms of the soil-water diffusivity and suction head. For early to intermediate times of flow, the similarity-reduction analysis describes adequately the calculated numerical-solution flow data for Yolo soil, as well as the measurement obtained experimentally on Salkum silty clay loam.

72-73:02G-014
THE INFILTRATION ENVELOPE: RESULTS FROM A THEORETICAL INFILTROMETER,
Smith, R.E.
Agricultural Research Service, Tucson, Arizona, Southwest Watershed Research Center.
Journal of Hydrology, Vol 17, No 1-2, p 1-22, October 1972. 13 fig, 4 tab, 10 ref.

Descriptors: *Infiltration , *Soil water movement, *Mathematical models, Numerical analysis, Unsaturated flow, Unsteady flow, Wetting, Porous media, Equations.

The theoretical partial differential equation for unsaturated soil moisture flow may be solved by a versatile numerical scheme designed for accurate simulation of infiltration from various patterns of rainfall. This model may be used to study the independent effects of soil type, initial soil moisture, rainfall rate and rainfall pattern. The solution is expressed as a simple parametric model for vertical infiltration. Infiltration from a suddenly ponded surface is shown to be an asymptotic limit to increasing rainfall rates. A single dimensionless for mula describes the infiltration decay curves for all soils, initial conditions, and rainfall rates tested, and another dimensionless relation predicts time to ponding under arbitrary rainfall patterns as a function of infiltrated rainfall depth. The effect of initial soil moisture is well described by a simple linear effect on the normalizing time in the dimensionless system. Uses and implications of these results are discussed.

72-73:02G-015
A HYDRAULIC MODEL FOR THE SIMULATION OF NON-HYSTERETIC VERTICAL UNSATURATED FLOW OF MOISTURE IN SOILS,
Wind, G.P.
Institute for Land and Water Management Research, Wageningen (Netherlands)
Journal of Hydrology, Vol 15, No 3, p 227-246, March 1972. 11 fig, 1 tab, 5 ref.

Descriptors: *Unsaturated flow, *Hydraulic models, *Infiltration, Drainage, Seepage, Soil-water movement, Model studies, Unsteady flow, Hydraulic conductivity, Capillary conductivity, Saturated flow, Hysteresis.

A hydraulic model used to simulate infiltration and drainage processes in soils of low permeability was built. It consists of a number of vessels, each simulating a layer of soil with its moisture characteristic, connected by a number of tubes, simulating capillary conductivity. The model reacts in nearly the same manner as the soil would, according to knowledge of the flow processes and parameters. The model can be used to study nonsteady state infiltration and drainage processes.

72-73:02G-016
HYDRATION OF CATIONS ADSORBED ON A CLAY SURFACE FROM THE EFFECT OF WATER ACTIVITY ON ION EXCHANGE SELECTIVITY,
Laudelout, H., Van Bladel, R., and Robeyns, J.
Louvain University, (Belguim)
Soil Science Society of America Proceedings, Vol 36, No 1, p 30-34, January-February 1972. 7 fig, 15 ref.

Descriptors: *Cation adsorption, *Clay minerals, *Ion exchange, Thermodynamics, Water chemistry, Hydration, Salinity, Trace elements, Adsorption.

Ion exchange equilibria for four pairs of singly charged ions in a montmorillonite clay were calculated at various total normalities of the equilibrium solution at 25 C. Only the trace region for the preferred ion was investigated. The effect of solvent activity on the selectivity coefficient was established; in each case the expected linear relationship between their logarithms was observed. The values for the differences of the ion hydration numbers calculated from this purely thermodynamic relationship were consistent and were comparable with values that could be deduced from basal spacings or anion exclusion volume data.

72-73:02G-017
AN IMPROVED FORM OF SOIL-WATER DIFFUSIVITY FUNCTION,
Ahuja, L.R., and Swartzendruber, D.
Purdue University, Lafayette, Indiana. Department of Agronomy.
Soil Science Society of America Proceedings, Vol 36, No 1, p 9-14, January-February 1972. 5 fig, 1 tab, 25 ref.

Descriptors: *Infiltration, *Diffusivity, *Soil water movement, *Computer programs, Numerical analysis, Saturated flow, Unsaturated flow, Hydraulic conductivity, Soil water, Soil moisture.

Soil-water diffusivity is expressed by a functional form which becomes infinite as the soil-water content approaches a constant value, such as the saturated or near-saturated value. The function begins at zero value, and shows an approximately exponential rise in the intermediate soil-water content range. When combined with an unsaturated hydraulic function, qualitatively reasonable forms for the relationship between water and suction head can be inferred. A computer program was developed to determine the characterizing parameters in the function by a least-squares fit to experimental data for horizontal water absorption. The program uses an optimum-seeking technique with numerical solutions of the flow equations as obtained by Philip's method. For different types of soils and several bulk densities, the new functional form was compared with the commonly used exponential expression and was found to be more representative.

72-73:02G-018
DIFFUSION OF ZINC IN SOIL: I. THE INFLUENCE OF SOIL MOISTURE,
Warncke, D.D., and Barber, S.A.
Purdue University, Lafayette, Indiana. Department of Agronomy.
Soil Science Society of America Proceedings, Vol 36, No 1, p 39-42,
January-February 1972. 1 fig, 5 tab, 9 ref.

Descriptors: *Diffusion, *Zinc radioisotopes, *Trace elements, *Soil moisture, Soil water movement, Adsorption, Ion transport, Aqueous solutions, Tracers, Soil chemistry.
Identifiers: *Zinc

Effective zinc diffusion coefficients were determined at several soil moistures on six soils by allowing Zn-65 to diffuse from the soil into cation exchange resin paper on the surface of the soil. At 13% volumetric moisture diffusivity values ranged from 10 to the minus 11th power to 10 to the minus 8th power sq cm/sec, with the range narrowing as the soils approached moisture saturation. In five of six soils, the effect of increasing moisture level on diffusivity could be explained by its effects on tortuosity and on solution Zn concentration. When solution Zn remained constant as moisture level increased, the relation between diffusivity and volumetric moisture was hyperbolic. When solution Zn level dropped as moisture increased, diffusivity changed very little.

72-73:02G-019
LEACHING OF A SURFACE LAYER OF SODIUM CHLORIDE INTO TILE DRAINS IN A SAND-TANK MODEL,
Mulqueen, J., and Kirkham, D.
Iowa State University, Ames
Soil Science Society of America Proceedings, Vol 36, No 1, p 3-9, January-February 1972. 7 fig, 2 tab, 13 ref.

Descriptors: *Leaching, *Saline soils, *Soil chemistry, *Land reclamation, Soil water movement, Model studies, Hydraulic models, Chlorides, Salts, Saline water systems.

The leaching of NaCl through tile drains from a surface layer of salinized sand was studied in a sand-tank model. Each experiment was conducted with a steady-state, arch-shaped water table maintained by recharge from a battery of capillary tubes that gave a uniform infiltration over the model. All the salt was leached from the model. Intense fingering developed in all experiments in which a salinized layer was used. Fingering caused a rapid and erratic redistribution of salt within the model and an erratic variation in the salinity of the drainage water until about 1 pore volume had drained. The higher the initial sand salinity, the more intense was the fingering, the longer were the fingers, and the higher were the finger velocities. The behavior of the fingering transition zone was controlled by the interaction between the density gradients and the hydraulic gradient; this latter depends on the recharge rate and the drain spacing. The salinity of the outflow drainage water rose quickly to a peak and then declined almost as quickly for a short period, after which it reduced more gradually. After about 1 pore volume had drained, the salinity of the drainage water declined exponentially in all salinized experiments. Experimental curves fitted closely to an exponential relationship except initially and where fingering resulted in erratic variations.

72-73:02G-020
DIFFUSION OF ZINC IN SOIL: II. THE INFLUENCE OF SOIL BULK DENSITY AND ITS INTERACTION WITH SOIL MOISTURE,
Warncke, D.D., and Barber, S.A.
Purdue University, Lafayette, Indiana. Department of Agronomy.
Soil Science Society of America Proceedings, Vol 36, No 1, p 42-46, January-February 1972. 4 fig, 3 tab, 13 ref.

Descriptors: *Diffusion, *Zinc radiosotopes, *Trace elements, *Soil moisture, Soil water movement, Adsorption, Ion transport, Aqueous solutions, Tracers, Soil chemistry.
Identifiers: *Zinc.

Effective zinc diffusion coefficients were determined at four soil bulk densities and three moisture levels in five salt loam soils. The tortuosity of the diffusion path for each set of soil conditions was estimated from Cl-36 diffusion data. In each soil and for each soil moisture level the diffusion path was least tortuous near 1.3 g/cc. The order for the influence of soil bulk density on tortuosity was 1.6>15.>1.1>1.3 g/cc. Soil bulk density interacted significantly with soil moisture in affecting the Zn diffusion coefficients. The maximum rate of Zn diffusion dit not always occur at a soil bulk density of 1.3 g/cc where the diffusion path was least tortuous. At 20 to 30% moisture the Zn diffusion rate reached a maximum near 1.5 g/cc. As the soil moisture was increased, a reduction in the effect of the interaction of Zn with the soil was greater than the effect of tortuosity in determing the effective rate of Zn diffusion in each soil. When the bulk density was increased from 1.5 to 1.6g/cc, an increase in both the degree of interaction and tortuosity combined to cause a sharp decrease in the Zn diffusion coefficient.

72-73:02G-021
FRACTIONATION OF CATION EXCHANGE CAPACITY FOR ASSESSING SOIL AND WATER SODICITY,
Bower, C.A., and Rhoades, J.D.
Agricultural Research Service, Riverside, California. Salinity Lab.
Soil Science Society of America Proceedings, Vol 36, No 1, p 174-175, January-February 1972. 1 tab, 7 ref.

Descriptors: *Hydraulic conductivity, *Ion exchange, *Clay minerals, Cation exchange, Potassium, Regression analysis.
Identifiers: *Vermiculite.

Soils containing appreciable amounts of vermiculite react atypically to Na. The regression coefficient of the relation between the exchangeable-sodium ratio and the sodium-adsorption ratio is appreciably greater for soil vermiculites than for montmorillonite and most soils. Further, at constant salt concentration, the exchangeable-sodium percentage associated with a given percentage decrease in hydraulic conductivity is greater for high-vermiculite than for low-vermiculite soils. For eight soils having a wide range of vermiculite contents, the exchangeable-sodium percentage required to cause a 25% reduction in hydraulic conductivity at a salt concentration of about 10 meq/liter was highly correlated (r=0.95) with cation exchange capacity after K fixation.

72-73:02G-022
USE OF PHYSICAL METHODS TO EXPAND SOIL SURVEY INTERPRETATIONS OF SOIL DRAINAGE CONDITIONS,
Bouma, J.
Wisconsin University, Madison. Department of Soil Science.
Soil Science Society of America Proceedings, Vol 37, No 3, p 413-421, May-June 1973. 9 fig, 36 ref.

Descriptors: *Hydraulic conductivity, *Model studies, *Soil water movement, Numerical analysis, Hydraulic models, Permeability, Soil physical properties, Soil surveys, Soil physics.

Complex numerical procedures and simple approximate physical methods, both requiring hydraulic conductivity and moisture retention data, can be used to calculate hydrodynamic soil behavior for a variety of simplified boundary conditions. Two approximate methods were applied to four Wisconsin soils in which measurements of hydraulic conductivity had been made in
Two soils that had been placed previously in different drainage classes on the basis of differences in soil mottling, actually had comparable hydrologic properties. Soil survey methods do not provide the quantitative data needed for predicting what soil behavior will be under environmental conditions that have changed temporarily or permanently.

72-73:02G-023

ANION EXCLUSION AND COUPLING EFFECTS IN NONSTEADY TRANSPORT THROUGH UNSATURATED SOILS: I. THEORY,

Bresler, E.
Volcani Inst. of Agricultural Research, Bet-Dagan (Israel) Department of Soil Physics.
Soil Science Society of America Proceedings, Vol 37, No 5, p 663-669, September-October 1973. 4 fig, 1 tab, 22 ref.

Descriptors: *Dispersion, *Soil water movement, *Ion exchange, *Osmosis, *Ion transport, Mathematical models, Numerical analysis, Clays, Simulation analysis, Unsaturated flow, Adsorption.

A simulation model for the simultaneous transport of anions and water takes into account physicochemical interaction between the solutes and the soil matrix. The effects of convection, ionic diffusion, methanical dispersion, anion exclusion (negative adsorption), and coupling phenomena are considered jointly. The dependence of the osmotic efficiency coefficient and anion exclusion of soil water content and solution concentration are estimated from diffuse double-layer theory and hydrodynamic considerations. These estimates compare favorably with available data on clays and soils. The nonsteady flow equations are solved by a numerical approach that eliminates numerical dispersion. An infiltration experiment was characterized by relatively high water contents and rapid flow; this showed that osmotic gradients are of minor importance. A slight anion exclusion brought about some improvement in the comparison between the theoretical data.

72-73:02G-024

WATER RECHARGE IN A SOIL WITH SHRINKAGE CRACKS,

Blake, G., Schlichting, E., and Zimmerman, U.
Hohenheim University, Stuttgart-Hohenheim (West Germany)
Soil Science Society of America Proceedings, Vol 37, No 5, p 669-672, September-October 1973. 4 fig, 2 tab, 8 ref.

Descriptors: *Infiltration, *Recharge, *Soil water movement, Interstices, Tracers, Soil physical properties, Tritium, Expansive soils, Shrinkage, Permeability, Hydraulic conductivity.
Identifiers: *Shrinkage cracks.

Flow of water was studied in a relatively dry Pelosol characterized by fine shrinkage cracks between peds. The coefficient of linear expansion was 0.115 in peds of the Bva horizon between oven dryness and 0.3 bar moisture content. After a prolonged period in which evapotranspiration exceeded rainfall, 200 micro Ci of tritium were added with 100 liters of water to a plot 1.4 by 1.4 m. Replicated soil samples were taken after 24 hours and again 14 days later. Tritiated water was not confined to surface layers, about half being found below the 20-cm depth. Small amounts were found to the 100 cm sampling depth. Tritiated water did not wet the surface layers to the 0.3 bar percentage. Water additions of 765 mm applied to an adjoining plot over a period of 1 month showed gradual accumulation in the surface horizons of the profile rather than wetting to field capacity in layers that wet from the soil surface downward. These results are interpreted to indicate that water flowed down fine cracks in A and B horizons as free water, some of it soaking into the ped walls, or running into C horizon. This was confirmed by measurements of the tritium concentration on crack walls. It was significantly higher on ped surface in the Bva horizon than in soil taken from within the peds.

72-73:02G-025

VERTICAL INFILTRATION INTO A LAYERED SOIL,

Aylor, D. E., and Parlange, J. V.
Connecticut Agricultural Experiment Station, New Haven, Department of Ecology.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 673-676, September-October 1973. 3 fig, 8 ref.

Descriptors: *Infiltration, *Unsaturated flow, *Soil horizons, *Equations, Anisotropy, Soil structure, Soil Physical properties, Mathematical studies, Wetting, Saturated flow, Hydraulic conductivity.

An analytical model describes the soil moisture profiles for vertical infiltration into a layered soil (a fine textured layer over a coarser layer). For the case of constant imposed flux of water at the surface, the effect of an initial soil moisture content that increases with depth causes a steepening of the moisture profile; and the effect of the discontinuity in soil texture at the interface causes an accumulation of water above the interface in the fine textured soil. The technique is easy to apply and gives results which are in good agreement with experiment and substantially better than those obtained by computer simulation.

72-73:02G-026
EFFECTIVE AVAILABLE WATER AND ITS RELATION TO EVAPOTRANSPIRATION RATE, DEPTH OF WETTING, AND SOIL TEXTURE,
Miller, D. E., and Aarstad, J. S.
Agricultural Research Service, Prosser, Washington.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 763-766, September-October 1973. 6 fig, 3 tab, 6 ref.

Descriptors: *Soil moisture, *Available water, *Evapotranspiration, Field capacity, Moisture content, Drainage, Irrigation.

The effect of evapotranspiration (Et) rate on effective available water (EAW) was evaluated for three soils ranging in texture from sand to silt loam, at evapotranspiration rates of about 0.4 to 1.3 cm per day, and at two depths of wetting. In all cases, as evapotranspiration rate increased, drainage following irrigation decreased and as a result EAW increased. The increase in EAW due to Et rate was relatively greater in the sand than in the finer textured soils. If only midsummer Et rates are considered, EAW may be estimated quite well from a field capacity test, provided soil depth and soil texture are considered in determining the sampling time for characterizing field capacity. If usable water is referenced to some safe depletion level rather than to the 15-bar percentage, the effect of Et is more important. EAW is influenced differently by depth of wetting in different textured soils.

72-73:02G-027
DEEP PLOWING AND CHEMICAL AMENDMENT EFFECT ON A SODIC CLAYPAN SOIL,
Sandoval, F. M., Bond, J. J., and Reichman, G. A.
United States Department of Agriculture, Agricultural Research Service, Mandan, North Dakota.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 681-684, 687, July-August, 1972. 4 fig, 5 tab, 13 ref.

Descriptors: *Soil management, *Deep tillage, *Soil amendments, Crop production, Cultivation, Soil properties, Soil chemistry, Soil profiles, Fallowing, Soils.

Deep plowing and chemical amendments improved a Solonetzic soil, increased barley yields, and substantially increased wheat yields under the dryland conditions of western North Dakota. The Rhoades silty clay loam, which had a shallow dense sodic claypan, was plowed ititially to 6, 12, and 24-inch depths with and without soil amendments. Split plots were alternately fallowed and cropped for 5 years. Barley was grown 4 years and wheat on the 5th year. Crop yield increases attributed to deep plowing appeared to be associated with greater soil water availability for crop use and for soil leaching. Soil improvement was evidenced by the reduction of bulk densities and lessened saline sodic soil conditions. Hardness of the soil crust was reduced by deep plowing, and amendments further increased soil friability. The 5th year after deep tillage and amendment treatments, spring wheat yields were 1,170, 1,570, and 1,885 pounds per acre for the 6, 12, and 24-inch plowing depths, respectively.

72-73:02G-028
HYDRODYNAMICS OF BORDER IRRIGATION ADVANCE,
Kincaid, D. C., Heermann, D. F., and Kruse, E. G.
United States Department of Agriculture, Mitchell, Nebraska.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 674-680, July-August, 1972. 14 fig, 1 tab, 10 ref.
(See 72-73:04A-007)

72-73:02G-029
SPRINKLER PRECIPITATION GAGE ERRORS,
Kohl, R. A.
Snake River Conservation Research Center, Kimberly, Idaho.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 264-265, 271, March-April, 1972. 2 fig, 1 tab, 7 ref.

Descriptors: *Irrigation practices, *Sprinkler irrigation, *Precipitation gages, Uniformity coefficient, Evaporation control, Evaporation.

A number of different types of precipitation gages have been tried with sprinkler irrigation. The main problem encountered has been that of evaporation losses from the container. Covering the water with oil had little effect since much of the evaporation took place from droplets clinging to the walls above the oil. A 250 millileter separatory funnel filled with oil was tested and found to be quite successful. As the water enters the oil is displaced into another container. The problem of splash losses does still exist with this method.

72-73:02G-030
PERFORMANCE OF A TILE DRAINAGE SYSTEM: AN EVALUATION OF A TILE DESIGN AND MANAGEMENT,
Perrier, E. R., MacKenzie, A. J., Grass, L. B., and Shull, H. H.
United States Department of Agriculture, Agricultural Research Service, Urbana, Illinois,
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 440-444, May-June, 1972. 6 fig, 6 tab, 15 ref.

Descriptors: *Drainage, *Drainage effects, *Drainage practices, Drainage systems, Subsurface drainage, Tiles, Drainage area, Drainage engineering, Irrigation practices.

This study compared the steady and unsteady-state drainage relations measured in the field to determine the performance and required management of an existing drainage system. The data were obtained from an 80 acre cotton field in California's Imperial Valley. The soil is a Holtville silty clay loam highly stratified, typical of the area. Various drainage design equations were compared to the measured data. Use of the tile lines for irrigation was also investigated. Results indicate that all of the equations only approximate the actual operation of the system. The use of the tile lines for irrigation showed promise. Numerous conclusions and observations by the authors are presented.

72-73:02G-031
A LARGE, UNDISTURBED, WEIGHING LYSIMETER FOR GRASSLAND STUDIES,
Armijo, J. D., Twitchell, G. A., Burman, R. D., and Nunn, J. R.
Wyoming University, Agricultural Engineering Division, Laramie.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 827-830, September-October, 1972. 6 fig, 7 ref.

Descriptors: *Lysimeters, *Moisture meters, *Evapotranspiration, Moisture content, Runoff, Water loss, Tunneling machines.

A large weighing type lysimeter was installed in the high plains of northeastern Colorado. The unit consists of a steel tank 10 feet in diameter and 4 feet deep. The container is made of 1-inch thick steel plate. The unit rests on a weighing mechanism consisting of a counter balance and electronic load cells. The soil in the lysimeter is undisturbed with native vegetation. This was accomplished using the tank as a large coring tube to cut out the undisturbed core. All of the related apparatus is placed underground except for a small access manhole located 18 feet from the edge of the unit. Data collection has just begun. Total cost for the unit and installation was $51,000.

72-73:02G-032
WHEAT AND GRAIN SORGHUM IRRIGATION IN A WIDE BED-FURROW SYSTEM,
Allen, R. R., and Musick, J. T.
United States Department of Agriculture, Agricultural Research Service, Bushland, Texas.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, p 61-63, January-February, 1972. 1 tab, 4 fig, 7 ref.

Descriptors: *Irrigation practices, *Furrow irrigation, *Irrigation design, Irrigation efficiency, Irrigation, Infiltration rates, Wheat, Grain sorghum, Agricultural engineering.
Identifiers: Row crops, Wide-bed furrows.

A wide bed-furrow system was tested for irrigation of winter wheat and grain sorghum on a slowly permeable clay loam in the Southern High Plains. The system consisted of 60-inch spaced furrows separating relatively broad flat beds about 40 inches wide. Wheel traffic zones were maintained along the center of the beds separate from water furrows. The wide bed-furrow system was compared with conventional 40-inch bed-furrows where wheel traffic occurs in irrigation furrows. Beds and furrows were maintained in place during a second crop by no-till seeding grain sorghum after wheat and using chemical weed control. The wide bed-furrow system was successfully managed for production of both winter wheat and grain sorghum. Yields from 60-inch bed-furrows were similar to those from the 40-inch spacing. Water intake during irrigation of wide bed-furrows on the 1,000-foot length of run was similar to 40-inch conventional bed-furrows during a winter irrigation of wheat but averaging 23 percent less during three spring irrigations, and 19 percent less during two seasonal irrigations of grain sorghum.

72-73:02G-033
DEVELOPMENT OF ASPHALT MOISTURE BARRIER EQUIPMENT,
Fischer, R. C.
International Harvester Company, Hinsdale, Illinois.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 630-631, July-August, 1972. 2 fig, 6 ref.

Descriptors: *Soil moisture, *Asphalt, Linings, Soil asphalt, Moisture availability, Deep percolation, Groundwater movement, Root zone.
Identifiers: Moisture barrier.

Prototype equipment for installation of asphalt water barrier under sandy farmland has attained rates of 1½ acres per hour. Installation requires a tractor of 200 horsepower and 1000 gallons of asphalt per acre. Predictions show that some vegetable crops will return the installation price of $250 per acre within three years. While some corn areas have taken five years. Asphalt barrier will conserve water and plant nutrients from leaching and reduce stream pollution. Asphalt barrier may become a significant factor in increasing the world food supply.

72-73:02G-034
NOTE ON THE INFILTRATION ADVANCE FRONT FROM BORDER IRRIGATION,
Parlange, J. Y.
Connecticut Agricultural Experiment Station, New Haven.
Water Resources Research, Vol. 9, No. 4, p 1075-1078, August 1973. 1 fig, 7 ref.

Descriptors: *Infiltration, *Border irrigation, Wetting, Soilwater movement, Numerical analysis, Water spreading.

The spreading of a water layer of constant thickness over a near horizontal soil surface is analyzed. The solution was applied consistently for short times. It estimates gravity effects properly by taking into account the pressure head of the water layer. An infiltration law valid for all times is also suggested to obtain numerical solutions in practical cases.

72-73:02G-035
A NUMERICAL AND SIMILARITY ANALYSIS OF INFILTRATION INTO CRUSTED SOILS,
Ahuja, L. R.
Purdue University, Lafayette, Indiana.
Water Resources Research, Vol. 9, No. 4, p 987-994, August 1973. 5 fig, 14 ref.

Descriptors: *Infiltration, *Soil water movement, *Surface sealing, *Impact (Rainfall), Numerical analysis, Soil surfaces, Earth-water interfaces, Soil compaction, Wetting, Unsaturated flow.
Identifiers: *Crusted soils, *Crusts.

One-dimensional, vertical infiltration of water through a crust of constant nonzero hydraulic resistance is theoretically examined by using a numerical solution and a similarity reduction of the problem. The soil-water content at the crust-soil interface increases with time to approach a predictable final steady water content asymptotically. A greater proportion of the flow takes place at intermediate to low water contents, and without an appreciable effect of gravity, as the crust resistance increases. For the water content at the crust-soil interface, the cumulative infiltration, and the wet front progress, simple expressions arise from the similarity reduction analysis, which is based on specific functional forms of the soil-water diffusivity and suction head, and a relatively small initial soil-water content. For early to intermediate times of flow, the similarity analysis describes adequately the calculated numerical solution flow data for Yolo soil. For intermediate to large times, a Green and Ampt type solution is linked to the similarity expression for cumulative infiltration with fair success.

72-73:02G-036
SIMULTANEOUS TRANSPORT OF SOLUTES AND WATER UNDER TRANSIENT UNSATURATED FLOW CONDITIONS,
Bresler, E.
Volcani Institute of Agricultural Research, Bet-Dagan (Israel), Department of Soil Physics.
Water Resources Research, Vol. 9, No. 4, p 975-986, August 1973. 5 fig, 22 ref.

Descriptors: *Unsaturated flow, *Unsteady flow, *Mass transfer, *Leaching, *Solutes, Groundwater movement, Convection, Dispersion, Mixing, Aqueous solutions, Path of pollutants, Numerical analysis, Finite element analysis.

Theoretical and mathematical tools are presented for analyzing transient one-dimensional vertical simultaneous transfer of noninteracting solute and water in unsaturated soils. The transient diffusion convection equation is solved numerically by an approach that eliminates the effect of numerical dispersion. The numerical results are compared with some analytical solutions for steady water flow. For transient infiltration the results are compared with field data. These comparisons indicate that the theory as well as the numerical method is reliable and can be used with confidence. Results are given for typical cases of infiltration, redistribution, and evaporation of water from the soil and their effect on dispersion coefficients and salt concentration profiles.

72-73:02G-0[illegible]
UNSTEADY RADIAL FLOW IN PARTIALLY SATURATED SOILS,
Fitzsimmons, D. W.
Idaho University, Agricultural Engineering Department, Moscow.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 912-918, September-October, 1972. 9 fig, 1 tab, 13 ref.

Descriptors: *Groundwater movement, *Hydrology, *Capillary conductivity, Soil moisture, Soil water, Groundwater, Moisture tension, Permeability, Soil physics, Darceys law, Base flow.

A numerical model for simulating horizontal imbibition in a radially symmetric flow system was developed. Unsteady radial flow from a cylindrical source into a partially saturated soil was studied in the laboratory and with the model to determine the effects of boundary and initial conditions on this type of flow. The model is based on the solution of the nonlinear partial differential equation for unsteady radial flow. A predictor-corrector modification of the Crank-Nicholson implicit difference method was used to solve the equation subject to the appropriate boundary and initial conditions. Imbibition was studied in the laboratory by allowing liquid to flow into a radially symmetric, soil-filled flow system at pressures which were below atmospheric. Tensiometers along the length of the flow system were used, in conjunction with a pressure transducer-indicator system, to measure the space-time distribution of capillary pressure head in the flow system. A balance was used to monitor the inflow during each test.

72-73:02G-038
SELECTING A METHOD FOR SCHEDULING IRRIGATION, USING A SIMULATION MODEL,
Lembke, W. D., and Jones, B. A., Jr.
Illinois University, Urbana-Champaign.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 284-286, March-April, 1972. 5 fig, 1 tab, 6 ref.
(See 72-73:04A-012)

72-73:02G-039
EVALUATION OF A FURROW MODIFYING DEVICE,
Gill, W. R.
United States Department of Agriculture, Agricultural Research Service, Auburn, Alabama.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 401-403, May-June, 1972. 5 fig, 3 tab, 2 ref.

Descriptors: *Soil treatment, *Cultivation, *Soil management, Soil physics, Soil texture, Soil properties.
Identifiers: *Plowing.

A study of the modification of a furrow slice indicates that a two-phase isolation and shearing of the soil slice may reduce the draft of a plow in certain soil conditions. The observed effect may be achieved by a reduction of compaction hardening or a partial loosening of the slice. While the undercutting and plowing of the slice may be done in separate operations it would appear that they can be simultaneously undertaken in a single operation if suitable space is provided between the tools. The forces on a plow may be beneficially altered by varying the parameters of an integrally mounted undercutting device. The use of a cutter reduces large lateral forces on plows.

72-73:02G-040
APPLICATION OF MONTE CARLO METHOD TO SOIL WATER MOVEMENT,
Shih, S. F., and Kriz, G. J.
North Carolina State University, Biological and Agricultural Engineering Department, Raleigh.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 897-901, September-October, 1972. 5 fig, 4 tab, 8 ref.

Descriptors: *Soil water movement, *Soil physics, *Drainage, Porosity, Permeability, Percolation, Darcey's law, Soil water, Soil moisture.

An approach for determining approximate solutions to problems of water movement in soils called the Monte Carlo method was presented and demonstrated. The basic concepts of the method are probability distribution, random number generations, and sampling techniques. The method was applied to solve problems of steady state and transient flow with and without recharge. Solutions were obtained directly by Monte Carlo techniques without analytically solving the flow equation. Using the method of solution described in this study, the hydraulic head or potential at any isolated point in the region can be obtained without solving for the hydraulic head or potential at the other mesh points. Comparisons of results obtained using the Monte Carlo method were made with values previously obtained by others. These comparisons indicate that the method is applicable to problems of water movement in soils.

72-73:02G-041
ESTIMATION PROCEDURES FOR RESPONSE FUNCTIONS OF CROPS TO SOIL WATER CONTENT AND SALINITY,
Yaron, D., Bielorai, H., Shalhevet, J., and Gavish, Y.
Hebrew University, Agricultural Economics Department, Jerusalem, Israel.
Water Resources Research, Vol. 8, No. 2, p 291-300, April, 1972. 6 tab, 4 fig, 21 ref.

Descriptors: *Salinity, *Irrigation practices, *Crop response, *Soil-water-plant relationships, Soil moisture, Soil chemistry, Crop production, Soil environment, Soil management, Agricultural engineering.

The specification and estimation procedures of the response functions of crops to soil water content and salinity are presented. The conceptual framework is discussed, and the application of the suggested procedures is illustrated by an analysis of two irrigation experiments. The possibility of positive correlations between soil salinity, soil water content, and crop yield is discussed, and possible erroneous evaluations of the effect of salinity on crop yield in such situations are pointed out.

72-73:02G-042
MEASUREMENT OF UNSATURATED HYDRAULIC CONDUCTIVITY BY THE CONSTANT OUTFLOW METHOD,
Overman, A. R., and West, H. M.
Florida University, Agricultural Engineering Department, Gainesville.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 6, p 1110-1111, November-December, 1972. 6 fig, 4 ref.

Descriptors: *Drainage engineering, *Soil physical properties, *Soil water movement, Soil physics, Permeability, Percolation, Soil moisture, Drainage, Drainage effects, Farm management.

Unsaturated hydraulic conductivity was calculated for Lakeland fine sand using constant outflow from the bottom end of a column. Beginning at saturation, hydraulic head was measured at several positions during drawdown. Water content was found to drop from 34.6 percent at saturation to approximately 11 percent and a corresponding tension of 60 cm. Drainage appears to continue toward constant water content rather than toward the true equilibrium condition of constant hydraulic head.

72-73:02G-043
WATER TABLE AND SOIL MOISTURE PROBABILITIES WITH TILE DRAINAGE,
Young, T. C., and Ligon, J. T.
Clemson University, Agricultural Engineering Department, Clemson, South Carolina.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 448-451, May-June, 1972. 8 fig, 13 ref.

Descriptors: *Subsurface drainage, *Tile drainage, *Model studies, Mathematical models, Computer models, Drainage, Drainage engineering, Closed conduits, South Carolina.

A method of soil moisture balance proposed by Ligon et al. (1965) was modified to include surface runoff and checked against field data. The agreement of the measured and computed data indicated that the soil moisture balance was adequate for estimating soil moisture conditions and excess moisture. The transient-flow equation development by van Schilfgaarde (1965) was verified with five months field data from a field drainage laboratory. The excess moisture estimated from the soil moisture balance was considered as the net accretion to the water table. The soil moisture balance and the transient-flow equation were combined in a computer model of the environment, soil and drainage system. An average decrease of 1.67 percent of soil moisture in the upper 30 inches of soil was found for a one-foot drop of the water table.

72-73:02G-044
SUBSURFACE DISTRIBUTION OF NONUNIFORMLY APPLIED SURFACE WATERS,
Hart, W. E.
Colorado State University, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 656-661, 666, July-August, 1972. 14 fig, 1 tab, 13 ref.
(See 72-73:04A-020)

72-73:02G-045
TENSIOMETER-PRESSURE TRANSDUCER SYSTEM FOR STUDYING UNSTEADY FLOW THROUGH SOILS,
Fitzsimmons, D. W., and Young, N. C.
Idaho University, Agricultural Engineering Department, Moscow.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 272-275, March-April, 1972. 6 fig, 10 ref.

Descriptors: *Soil moisture meters, *Tensiometers, *Soil water movement, Moisture tension, Pressure measuring instruments, Unsteady flow, Unsaturated flow, Soil water, Tension, Soil moisture, Irrigation.

A new, fast-acting system has been developed to nondestructively measure moisture content of soil. The system is based on the old tensiometer technique with two important changes. A tensiometer barrier material made of polyvinyl chloride is used. This allows the water to pass to or from the soil much more quickly than previous materials. Diaphragm-type pressure transducers which have extremely small full-scale volumetric displacements provide much faster readings. These units were used to investigate moisture movement. Descriptions of technique and apparatus along with results are presented.

72-73:02G-046
SHAPE FACTORS IN IRRIGATION WATER ADVANCE EQUATION,
Singh, P., and Chauhan, H. S.
Agricultural University, Agricultural Engineering Department, Pantnagar, Nainital, India.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR3, p 443-458, September, 1972. 10 fig, 1 tab, 9 ref.

Descriptors: *Irrigation practices, *Irrigation design, *Hydraulics, *Surface irrigation, Flow, Irrigation engineering, Infiltration, Infiltration rates, Soil mechanics, Soil physics, Irrigation.

Utilizing empirical advance and infiltration functions, relationships for surface and subsurface storage shape factors have been obtained. The surface and subsurface shape factors as expressed by these relationships are functions of time and infiltration characteristics of soil. Incorporating these relationships, a continuity equation has been written for advance of water in surface irrigation. The equation for advance of water compares well with field data and relationships of other workers.

72-73:02G-047
WATER-YIELD RELATIONS FOR NONFORAGE CROPS,
Downey, L. A.
New South Wales Department of Agriculture, Research Station, Leeton, Australia.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR1, p 107-115, March, 1972. 3 fig, 13 ref.

Descriptors: *Irrigation practices, *Water distribution (applied), *Water demand, *Water requirements, *Irrigation efficiency, Irrigation engineering, Soil moisture, Cost-benefit ratios, Evapotranspiration, Grains (crops), Irrigation, Water balance, Consumptive use.
Identifiers: Water deprivation, Agricultural products.

The relationship between soil moisture stress, evapotranspiration, and marketable yield of crops - where the yield is a reproductive organ or associated product - is examined. Under conditions of constant stress, yield is reduced as a linear function of stress. Where stress is applied at different stages in the development of the crop, no simple relationship exists. To predict yield from the water available or from evapotranspiration, the severity of stress and the physiological stage of development must be defined. A disproportionate reduction in yield is induced by water stress during the phases of reproduction corresponding to the period of peak evapotranspiration. Therefore, if irrigation engineers cannot plan their systems for times of peak demand, cost-benefit analyses should reflect probable yield reductions.

72-73:02G-048
RECYCLING AND RECOVERY OF NITROGEN, PHOSPHORUS, AND POTASSIUM BY COASTAL BERMUDAGRASS: II. UNDER GRAZING CONDITIONS WITH TWO STOCKING RATES,
Rouquette, F. M., Jr., Matocha, J. E., and Duble, R. L.
Texas A & M University, Overton.
Journal of Environmental Quality, Vol. 2, No. 1, p 129-132, January-March, 1973. 3 fig, 1 tab, 27 ref.
(See 72-73:05B-041)

72-73:02G-049
RECYCLING AND RECOVERY OF NITROGEN, PHOSPHORUS, AND POTASSIUM BY COASTAL BERMUDAGRASS: I. EFFECT OF SOURCES AND RATES OF NITROGEN UNDER A CLIPPING SYSTEM,
Matocha, J. E., Rouquette, F. M., Jr., and Duble, R. L.
Texas A & M University, Overton.
Journal of Environmental Quality, Vol. 2, No. 1, p 125-129, January-March, 1973. 5 fig, 2 tab, 17 ref.
(See 72-73:05B-042)

72-73:02G-050
CHEMICAL DISTRIBUTION OF RESIDUAL FERTILIZER NITROGEN IN SOIL AS REVEALED BY NITROGEN-15 STUDIES,
Allen, A. L., Stevenson, F. J., and Kurtz, L. T.
Langston University, Langston, Oklahoma.
Journal of Environmental Quality, Vol. 2, No. 1, p 120-124, January-March, 1973. 5 fig, 18 ref.
(See 72-73:05B-043)

72-73:02G-051
MOVEMENT OF NITRATE NITROGEN IN SOME GRASSLAND SOILS IN SOUTHERN ALBERTA,
Sommerfeldt, T. G., and Smith, A. D.
Canada Department of Agricultural Research Stations, Lethbridge, Alberta.
Journal of Environmental Quality, Vol. 2, No. 1, p 112-115, January-March, 1973. 5 fig, 3 tab, 14 ref.
(See 72-73:05B-044)

72-73:02G-052
INCREASED DENITRIFICATION IN SOILS BY ADDITIONS OF SULFUR AS AN ENERGY SOURCE,
Mann, L. D., Focht, D. D., Joseph, H. A., and Stolzy, L. H.
California University, Riverside.
Journal of Environmental Quality, Vol. 1, No. 3, p 329-332, July-September, 1972. 1 fig, 6 tab, 18 ref.
(See 72-73:05B-049)

72-73:02G-053
NITRATE IN UNSATURATED ZONE OF AN ALLUVIAL SOIL IN RELATION TO FERTILIZER NITROGEN RATE AND IRRIGATION LEVEL,
Adriano, D. C., Pratt, P. F., and Takatori, F. H.
California University, Riverside.
Journal of Environmental Quality, Vol. 1, No. 4, p 418-422, October-December, 1972. 5 fig, 3 tab, 10 ref.
(See 72-73:05B-050)

72-73:02G-054
CONCENTRATIONS OF NITROGEN, PHOSPHORUS, POTASSIUM, AND TOTAL SOLUBLE SALTS IN SOIL SOLUTION SAMPLES FROM FERTILIZED AND UNFERTILIZED HISTOSOLS,
Hortenstine, C. C., and Forbes, R. B.
Florida University, Gainesville.
Journal of Environmental Quality, Vol. 1, No. 4, p 446-449, October-December, 1972. 5 fig, 9 ref.
(See 72-73:05B-052)

72-73:02G-055
DISTRIBUTION AND CHEMISTRY OF PHOSPHORUS IN AN ALBAQUALF SOIL AFTER 82 YEARS OF PHOSPHATE FERTILIZATION,
Kao, C. W., and Blanchar, R. W.
Missouri Agricultural Experiment Station.
Journal of Environmental Quality, Vol. 2, No. 2, p 237-240, April-June, 1973.

2 fig, 3 tab, 25 ref.

Descriptors: *Phosphates, *Fertilizers, *Leaching, Solubility, Nutrient removal, Phosphorus, Soil chemistry, Chemicals, Dispersion.

The distribution of phosphorus in a fertilized and unfertilized Mexico silt loam soil was measured. After 82 years of phosphorus fertilization, the added phosphorus was found in Ap (0-23 cm), smaller amounts in the A and B, and B2 (23-86 cm), and large amounts in the B3 and upper C (86-137 cm) horizons. In the fertilized soil the distribution of phosphorus, particularly inorganic and available, was similar to that of original phosphorus in the soil profile. The phosphorus adsorption capacities of fertilized and unfertilized soils were similar. These data indicated that the soil fertilized with phosphorus for 82 years had nearly double the total phosphorus content, but the ability of the soil to adsorb additional phosphorus was the same. Ion products indicated that the phosphorus level in the soil solution was controlled by the solubility of strengite.

72-73:02G-056
SOIL CHANGES CAUSED BY EROSION CONTROL TREATMENTS ON A SALT DESERT AREA,
Wein, R. W., and West, N. E.
New Brunswick University, Fredericton, Department of Biology.
Soil Science Society of America, Proceedings, Vol. 37, No. 1, p 98-103, January-February 1973. 2 fig, 3 tab, 26 ref.

Descriptors: *Soil investigations, *Saline soils, *Salt tolerance, *Soil water movement, *Sedimentation rates, Utah, Colorado River Basin, Furrow irrigation, Drainage engineering, Watersheds (basins), Bulk density, Desert plants, Deserts, Plant physiology, Soil types, Erosion control.
Identifiers: Upper Colorado River Basin, Salt Desert.

The upper Colorado River Basin is comprised in part of 18 million acres of Utah's erosion-prone watershed. Although this area contributes only 5 percent of the water to the Colorado River, it contributes 44 percent of the sediment. This has resulted in inadequate drainage due to the filling of reservoirs, reducing storage capacity, and salt accumulation in the catchment basins of gully plugs and furrows. A comparison of Chipeta Series soil and an unnamed soil revealed that infiltration rates decreased in the Chipeta Series soil as clay accumulated on the gully plug floor so that during rainstorms the water supply was essentially sealed off from the subsoil, therefore evaporating into an arid environment. The salt buildup caused by slow infiltration appears to be inevitable. In the Chipeta Series soil, or in very saline soils, a salt buildup could occur before the gully plugs fill with sediment to a level where breaching occurs. The gully plug is essentially self destructive in soils of saline-sodic nature because the short term increase in vigor and density of native species is cancelled out by the loss of plants during construction and during the return to status quo.

72-73:02G-057
A LIMITING FLUX CONDITION IN INFILTRATION INTO HETEROGENEOUS POROUS MEDIA,
Watson, K. K., Perrens, S. J., and Whisler, F. D.
New South Wales University, Kensington, (Australia), Department of Civil Engineering.
Soil Science Society of America Proceedings, Vol. 37, No. 1, p 5 - 10, January-February 1973. 3 fig, 2 ref.

Descriptors: *Infiltration, *Unsaturated flow, *Zone of aeration, *Porous media, Hydraulic conductivity, Soil water movement, Wetting, Equations, Heterogeneity.

Infiltration into a porous medium in which the hydraulic conductivity increases with depth quickly approaches a limiting flux condition. This condition is defined by a profile of pressure head which is tangential to the profile water entry value. Equations are given to enable the values of the limiting flux and the elevation of the point of contact to be calculated in terms of the material properties and the boundary conditions. Below the limiting flux an unsaturated zone exists, and wetting in this zone continues under the condition of limiting flux. A method is given to determine the pressure and water content profiles for this zone.

72-73:02G-058

CHLORIDE MOVEMENT IN UNDISTURBED SWELLING CLAY SOIL,

Kissel, D. E., Ritchie, J. T., and Burnett, E.

Texas A & M University, College Station.

Soil Science Society of America Proceedings, Vol. 37, No. 1, p 21-24, January-February 1973. 3 fig, 3 tab, 13 ref.

Descriptors: *Leaching, *Chlorides, *Expansive soils, *Expansive clays, *Pores, Tracers, Fluorescent dye, Adsorption, Ion exchange, Dispersion, Percolation, Soil water movement, Salts, Soil structure, Porosity, Permeability, Hydraulic conductivity.

Downward leaching of Cl followed large, continuous soil pores in saturated, swelling clay soils. Using water-soluble fluorescein as a tracer, distinct small areas of the soil contained fluorescenin, whereas nearby areas contained no visible fluorescein after water with Cl and fluorescein was ponded at the surface for 1.5 days. Breakthrough curves of a large saturated core of undisturbed swelling clay soil indicated that Cl was moving quite rapidly through large connected pores. In the undisturbed swelling clay soil, the volume of soil water not containing Cl was about 60%; when the disturbed soil was repacked to the same density this value decreased to 40%. More of the original soil solution was eluted from long undisturbed cores than from short undisturbed cores of the same diameter before Cl appeared in the effluent. The longer core wall blocked more connected flow paths which were not vertical.

72-73:02G-059

INFLUENCE OF WATER CONTENT ON ELECTRICAL CONDUCTIVITY OF THE SOIL,

Gupta, S. C., and Hanks, R. J.

Utah State University, Logan, Department of Soil Science and Biometeorology.

Soil Science Society of America Proceedings, Vol. 36, No. 6, p 855-857, November-December 1972. 3 fig, 2 tab, 6 ref.

Descriptors: *Electrical studies, *Soil water, *Salinity, *Soil moisture meters, Mass transfer, Electrical conductance, Conductivity, Geophysics, Moisture content.

The four-probe system of measuring electrical conductivity of soil eliminates the time lag error, but introduces the problem of correcting the changes in conductivity caused by water content. Regression equations developed to estimate saturation of 1:5 extract electrical conductivity from four-probe conductivity and water content gave correlation coefficients of 0.75 and 0.90, respectively. Correlations for individual soils were generally higher than the combined soils. The regression equation relating the ratio of four-probe conductivity to four-probe conductivity at saturation with water content yields a correlation coefficient of 0.88 for the combined soil data.

72-73:02G-060
HORIZONTAL INFILTRATION INTO LAYERED SOILS,
Reichardt, K., Nielsen, D. R., and Biggar, J. W.
California University, Davis, Department of Water Science and Engineering.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 858-863, November-December 1972. 10 fig, 1 tab, 11 ref.

Descriptors: *Infiltration, *Soil water movement, Percolation, Diffusivity, Wetting, Hydraulic conductivity, Stratification, Numerical analysis, Soil physical properties.
Identifiers: *Infiltration (Horizontal).

A numerical solution of the soil water movement equation is presented for horizontal infiltration into air-dry layered soils. The solution is based upon a scaled soil water diffusivity function common to six homogeneous soils and values of the microscopic characteristic length ascertained for each soil from homogeneous columns. Soil water content distributions and cumulative infiltration for different sequences of soil layers are analyzed. Agreement between experimental and theoretical infiltration profiles suggests a convenient means to study the influence of texture and hydraulic characteristics of different layers on the infiltration process.

72-73:02G-061
SOLUTIONS FOR MISCIBLE DISPLACEMENT OF SOIL WATER WITH TIME-DEPENDENT VELOCITY AND DISPERSION COEFFICIENTS,
Warrick, A. W., Kichen, J. H., and Thames, J. L.
Arizona University, Tucson, Department of Soils, Water and Engineering.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 863-867, November-December 1972. 3 fig, 2 tab, 12 ref.

Descriptors: *Infiltration, *Ion transport, *Mass transfer, *Soil water movement, Dispersion, Mixing, Aqueous solutions, Path of pollutants, Unsaturated flow, Percolation.

Miscible displacement processes with time-varying velocity and dispersion coefficients are examined. Simplified solutions utilizing arbitrary initial conditions are presented and used to simulate step and slug inputs of solutes into soil during infiltration of water. The solutions are used in the analysis of experimental data, both for field infiltration with a slug of solute and for psychrometric measurements of salt fronts in a laboratory sand column. Experimental data obtained for solute movement were more accurately described using time-increasing dispersion relationships than for constant values.

72-73:02G-062
THE NUMERICAL ANALYSIS OF INFILTRATION INTO HETEROGENEOUS POROUS MEDIA,
Whisler, F. D., Watson, K. K., and Perrens, S. J.
Agricultural Research Service, Phoenix, Arizona, Water Conservation Laboratory.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 868-874, November-December 1972. 10 fig, 7 ref.

Descriptors: *Infiltration, *Soil water movement, *Water spreading, Recharge, Numerical analysis, Hydraulic conductivity, Porous media, Unsaturated flow, Saturated flow.
Identifiers: Ponded infiltration.

Ponded infiltration into a heterogeneous porous medium was studied using a numerical solution of the flow equation. The medium was assumed to exhibit scale heterogeneity, the heterogeneity being specifically defined in terms of a linear variation of the resaturated hydraulic conductivity with depth. The spatial variation of the hydrologic characteristics was initially defined in terms of the water entry value of the medium at the point in question and an empirical relationship between the water entry value and the resaturated hydraulic conductivity. Pressure head and water content profiles were obtained for two hydraulic conductivity distributions and compared with that for a homogeneous soil having an average conductivity. The profiles reveal distinct regions that are different from the uniform case depending on whether the conductivity is increasing or decreasing with depth.

72-73:02G-063
WATER MOVEMENT IN UNDISTURBED SWELLING CLAY SOIL,
Ritchie, J. T., Kissel, D. E., and Burnett, E.
Agricultural Research Service, College Station, Texas.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 874-879, November-December 1972. 5 fig, 1 tab, 8 ref.

Descriptors: *Soil water movement, *Expansive soils, *Expansive clays, *Fracture permeability, Cracks, Laboratory tests, Tracers, Dye releases, Hydraulic conductivity.

Hydraulic conductivities of Houston Black clay were measured in two field basins, in relatively large undisturbed cores, and in small disturbed cores. Conductivities averaged about 2.5 cm/day for the field basins but were about 10 times less for the core samples. Using water tagged with fluorescein to displace deionized water in an undisturbed core, pores in distinctive isolated areas were found to be conducting most of the water. Water contained within structural units appeared to be inactive in the flow process when compared to water flow around the units.

72-73:02G-064
SOIL AIR PRESSURE AND WATER INFILTRATION UNDER BORDER IRRIGATION,
Dixon, R. M., and Linden, D. R.
Agricultural Research Service, Reno, Nevada.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 948-953, November-December 1972. 7 fig, 11 ref.

Descriptors: *Infiltration, *Border irrigation, *Edge effect, *Soil water movement, Wetting, Pressure, Mixing, Hydraulic conductivity, Pores, Interstices.
Identifiers: *Soil air displacement, *Soil air pressure.

Soil air pressure and water infiltration were measured during actual and simulated border irrigation of a uniform loam soil having a water table about 2 m beneath the surface. Displaced air pressure decreased downslope and across slope from center to edge of the border strips. A maximum displaced air pressure of 21 cm of water was observed in the upslope central part of the border strip. Air entrapment commonly occurred at a 50-cm depth next to border dikes but rarely occurred midway between dikes, which implies that water penetration was greatest in the region of lowest displaced air pressure. Displaced air pressure, building to a maximum of about 19 cm, reduced total infiltration by about one-third. Such pressure appears to impede infiltration mainly by preventing or retarding direct flow of surface water into and within open macropores. In the central region of the border strip where displaced air pressure exceeds the surface water head, macropores vent displaced soil air upward; whereas along the border dikes where surface head exceeds air pressure, macropores conduct free surface water downward. Soil air pressure and its infiltration effects are not negligible as is commonly assumed by Darcy-based flow theory, and soil air can be a useful tool for controlling infiltration in some important situations.

72-73:02G-065
LONG-TERM EFFECTS OF MANURE, FERTILIZER, AND PLOW DEPTH ON CHEMICAL PROPERTIES OF SOILS AND NUTRIENT MOVEMENT IN A MONOCULTURE CORN SYSTEM,
Vitosh, M. L., Davis, J. F., and Knezek, B. D.
Michigan Agricultural Experiment Station, East Lansing.
Journal of Environmental Quality, Vol. 2, No. 2, p 296-299, April-June, 1973.
5 tab, 20 ref.
(See 72-73:05B-057)

72-73:02G-066
NITROGEN LOSSES IN SURFACE RUNOFF FROM AGRICULTURAL WATERSHEDS ON MISSOURI VALLEY LOESS,
Schuman, G. E., Burwell, R. E., Piest, R. F., and Spomer, R. G.
United States Department of Agriculture, Lincoln, Nebraska.
Journal of Environmental Quality, Vol. 2, No. 2, p 299-302, April-June, 1973.
5 tab, 15 ref.
(See 72-73:05B-058)

72-73:02G-067
THEORY, DEVELOPMENT, AND UTILIZATION POTENTIAL OF THE BIOMILIEU CONCEPT,
Szekelyhidi, I. J.
Department of Army, Corps of Engineers, Chicago, Illinois.
Water Resources Bulletin, Vol. 8, No. 1, p 24-37, February, 1972. 11 fig, 6 ref.

Descriptors: *Bioindicators, *Biorhythms, *Ecology, Soil, Management, Environment, Biological communities, Computers, Computer models, Cost-benefit analysis.
Identifiers: *Biomilieu Theory, *Biomilieu index, Environmental quality index, Biocatalytic.

A quantitive engineering approach to analysis of total environment allowing for simultaneous consideration of a theoretically infinite number of quality indicators and physiological requirements is presented. Theory and fundamentals of a two-dimensional space and time function solution concerning a small estuarine-type environment is discussed. A three-dimensional solution is indicated. Input data may range from reconnaissance-type to the outputs of mathematical transport models. Applications are discussed with respect to environmental quality problems, availability of suitable data, and some areas of research where results could find immediate application.

72-73:02G-068
THE PERSISTENCE AND MOVEMENT OF PICLORAM AND 2, 4, 5-T IN SOILS,
Lutz, J. F., Byers, G. E., and Sheets, T. J.
North Carolina State University, Raleigh.
Journal of Environmental Quality, Vol. 2, No. 4, p 485-488, October-December, 1973. 1 fig, 5 tab, 24 ref.
(See 72-73:05B-065)

72-73:02G-069
FUNCTIONS TO PREDICT EFFECTS OF CROP WATER DEFICITS,
Stewart, J. I., and Hagan, R. M.
California University, Davis.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR4, p 421-439, December, 1973. 4 fig, 38 ref.
(See 72-73:03F-046)

72-73:02G-070
APPROXIMATE SOLUTION FOR UNCONFINED SEEPAGE,
Desai, C. S.
United States Army Engineer Division, Vicksburg, Mississippi.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR1, p 71-87, March,1973. 12 fig, 24 ref.
(See 72-73:02F-069)

72-73:02G-071
SIMULATION OF POST-IRRIGATION MOISTURE MOVEMENT,
Molz, F. J.
Auburn University, Civil Engineering Department, Auburn, Alabama.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR4, p 523-532, December, 1972. 9 fig, 1 tab, 12 ref.

Descriptors: *Irrigation, *Soil-water-plant relationships, *Soil water movement, *Drainage, Soil water, Root zone, Darcey's law, Mathematical models, Computer models, Root systems, Transpiration, Water loss.

Transpiration-induced moisture removal by the plant roots is represented by a negative source term in the Darcy equation. When soil is wetted to near saturation, moisture flow is initially downward due to gravity. As transpiration dries the upper soil layers, capillary suction reverses the Darcian flow. Upward water flux through soil has a maximum which occurs high in the root zone initially and gradually moves downward. Throughout much of time periods studied there was downward flow in portions of the soil-root system. Very little water, if any, was obtained by the plants from below the root zone, but considerable moisture was often lost to this region. As the soil-root system dries, a point is reached at which the Darcian moisture flux in soil can be neglected and the moisture removal process described by local extraction alone. When this occurs, the root geometry assumes major importance in determining the water supply available to a plant.

72-73:02G-072
PREFABRICATED FILTER-FIN FOR SUBSURFACE DRAINS,
Healy, K. A., and Long, R. P.

Connecticut University, Civil Engineering Department, Storrs.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR4, p 543-552, December, 1972. 5 fig, 1 tab, 5 ref.

Descriptors: *Drainage, *Drainage practices, Drainage systems, *Filters, Drainage engineering, Tile drainage, Subsurface drainage, Drains, Filtration, Seepage, Slope stabilization.
Identifiers: Fins, Underdrains.

The design and methods of installation of a prefabricated filter media for use with subsurface drains is presented. The filter media is fabricated from synthetic materials and can be used without special backfill. Methods of installing the prefabricated system in trenches and slopes are described. Results are presented from five field test installations comtaining a total length of 2,500 feet (762 m) of prefabricated underdrain. Costs for the underdrains are shown, and potential economics for slope stabilization and land drainage are indicated.

72-73:02G-073
PROBLEMS OF CHOOSING IRRIGATION TECHNIQUES IN A DEVELOPING COUNTRY,
Soltani-Mohammadi, G. R.
Pahlavi University, Shiraz, Iran.
Water Resources Research, Vol. 8, No. 1, p 1-6, February, 1972. 4 tab, 13 ref.
(See 72-73:04A-029)

72-73:02G-074
PERIODIC CHANGES IN THE IONIC CONCENTRATIONS OF SOME SUBMERGED SOILS OF BIHAR,
Biswas, D., Naphade, J. D., and Dhua, S. P.
Fertilizer Corporation of India, Sindri.
Agronomy Journal, Vol. 64, No. 3, p 336-338, 1972. Illus.

Identifiers: *Soil chemical properties, Ammonium, *Bihar (India), Carbonates, Chlorides, Fertilizers, Ions, Minerals, Oryza sativa M, Rice, Soils, Submerged soils.

The investigation was carried out under laboratory conditions to study the chemistry of submerged soils of Bihar to help in assessing their potentialities in meeting the nutritional requirements of the rice plant (Orza sativa L.). The soils were kept at 1:1.5 soil:water ratio and analyzed periodically for pH, electrical conductivity, soluble NH4+, Fe++, Mn++, P, Na+, K+, Ca++, CO3±, HCO3-, and Cl- on the 15th, 30th, 45th, and 60th day. The results show differential release of these nutrients in different soils with time. While the pH of acidic soils increased, that of alkaline soils decreased with the time of submergence. The pH of all soils fell between 6.50 and 8.50 on the 60th day. In general the peak values of Mn+++ and CO3± were noted on the 15th day, HCO3- and Cl- on the 30th day, and that of NH4+ between the 30th and 45th day after submergence. Most of the soils appear to be inherently deficient in N, P, K, Fe++, etc. and a good response of rice to fertilizer applications may be expected.

72-73:02G-075
EFFECT OF SOIL AIR MOVEMENT AND COMPRESSIBILITY ON INFILTRATION RATES,
LeVan Phuc, and Morel-Seytoux, H. J.
Colorado State University, Fort Collins, Department of Civil Engineering.

Soil Science Society of America Proceedings, Vol. 36, No. 2, p 237-241, March-April 1972. 7 fig, 15 ref.

Descriptors: *Infiltration, *Unsaturated flow, *Permeability, *Wetting, *Soil water movement, Hydraulic conductivity, Zone of aeration.
Identifiers: *Multiphase flow, Soil air displacement

Air flow and compressibility may affect significantly the infiltration rates and the saturation profiles of soils. When water infiltrates the soil, the air in the soil pores is pushed aside to make room for the water. With a lower no-flow boundary, air can only escape at the top, but its flow is impeded by water entering the soil. In the unsaturated (one-phase) flow theory two physical effects both of which tend to reduce infiltration are neglected, namely, the viscous resistance to airflow and the air compression ahead of the wetting front. Thus the two-phase flow theory, which includes these two effects, will necessarily predict lower infiltration rates than the unsaturated flow theory. So the infiltration curve for the semi-infinite medium calculated by the two-phase flow theory must, of necessity, lie below the curve that would be predicted by the unsaturated (one-phase) flow theory. In numerical experiments, the wetting front never reached the lower boundary during the infiltration stage. The saturation profiles near the surface indicate a clear shift toward a drier state to allow air to escape, thereby reducing the capacity of the soil to imbibe water.

72-73:02G-076
ON THE CALCULATION OF HYDRAULIC CONDUCTIVITY,
Jackson, R. D.
Agriculture Research Service, Phoenix, Arizona, Water Conservation Laboratory.
Soil Science Society of America Proceedings, Vol. 36, No. 2, p 380-382, March-April 1972. 2 fig, 1 tab, 12 ref.

Descriptors: *Hydraulic conductivity, *Unsaturated flow, *Soil water movement, Moisture content, Statistical methods, Laboratory tests.

Methods for calculating hydraulic conductivities of porous materials proposed by Marshall and by Millington and Quirk are similar except for the pore interaction term. This term is constant in the Marchall method. Equations for the two methods differ only by the exponent of the pore interaction term, which is 0 for Marshall's method and 4/3 for Millington and Quirk's. Data for four porous materials, for which the hydraulic conductivities, pressure heads, and water contents were determined on the same sample, were used in a statistical procedure to obtain a best fit value for the exponent. An exponent of 1 adequately predicted the measured conductivities. With this exponent, hydraulic conductivities for a field soil were calculated from a laboratory-determined pressure head-water content relation. Calculated and measured conductivities agreed to within the limits of error of measurement.

72-73:02G-077
SOLUBILITY AND SOLUBILITY PRODUCT OF GYPSUM IN SOIL SOLUTIONS AND OTHER AQUEOUS SOLUTIONS,
Bennett, A. C., and Adams, F.
Auburn University, Alabama, Department of Agronomy and Soils.
Soil Science Society of America Proceedings, Vol. 36, No. 2, p 288-291, March-April 1972. 2 fig, 3 tab, 10 ref.

Descriptors: *Gypsum, *Solubility, *Water chemistry, Sulfates, *Soil water,

Solutes, Chemical potential, Soil chemistry, Aqueous solutions, Electrolytes.
Identifiers: *Solubility product (Gypsum), *Soil solutions.

The solubility of gypsum was measured in several soils and dilute aqueous electrolytic media. The ionic strength of electrolytic media ranged from 0.059 to 0.314; the solubility product of gypsum in these solutions ranged from 0.0000213 to 0.0000279 and averaged 0.0000251. In soil solutions, the solubility product of gypsum ranged from 0.0000241 to 0.0000292 and averaged 0.0000273. The solubility product of gypsum in pure water was 0.0000258. The mean ionic activity coefficient of gypsum in solutions of different ionic strengths was computed using analytical data from aqueous electrolytic media and the known solubility product. The plot of this mean ionic activity coefficient versus the square root of gross solution ionic strength allowed accurate determination of the solubility product of gypsum in soil solutions using only analytical data.

72-73:02G-078

STEADY INFILTRATION FROM BURIED, SURFACE, AND PERCHED POINT AND LINE SOURCES IN HETEROGENEOUS SOILS: 1. ANALYSIS,

Philip, J. R.
Commonwealth Scientific and Industrial Research Organization, Canberra (Australia), Division of Environmental Mechanics.
Soil Science Society of America Proceedings, Vol. 36, No. 2, p 268-273, March-April 1972. 11 ref.

Descriptors: *Infiltration, *Steady flow, *Irrigation water, *Subsurface irrigation, *Soil water movement, Porous media, Soil moisture, Unsaturated flow, Numerical analysis, Hydraulic conductivity.
Identifiers: *Steady infiltration.

The quasilinearized steady infiltration equation is generalized to apply to heterogeneous soils with conductivity depending exponentially on both moisture potential and depth. Mathematical developments, including a theorem connecting surface and buried source solutions, follow closely those established previously for homogeneous soils. Solutions are found for buried, surface, and perched point and line sources. Physically relevant solutions are limited to the following ranges of the dimensionless coefficient of dependence of conductivity on depth: for buried and surface sources, zero or larger; for perched point sources, -1 or smaller; for perched line sources, greater than -1. The homogeneous medium with the zero coefficient is an extreme case for existence of buried and surface source solutions. Perched source solutions (relevant to subirrigation) exist only for soils with conductivity increasing rapidly with height above the impermeable base.

72-73:02G-079

INSTRUMENTATION EFFECTS ON ERRORS IN NUCLEAR METHODS FOR SOIL WATER AND DENSITY DETERMINATION,

Stone, J. F.
Oklahoma Sate University, Stillwater, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 36, No. 2, p 261-264, March-April 1972. 10 ref.

Descriptors: *Calibrations, *Nuclear moisture meters, *Instrumentation, *Soil moisture meters, Moisture meters, Nuclear meters, Soil water, Radioactivity techniques, Density.

Equations for calculating the errors of determination of the ratio commonly used in soil moisture determination by neutron scattering are discussed. Some of the errors due to random event counting, dead time, and drift phenomena not fully compensated for by the ratio method are held to 0 at the point where the count in the soil medium is equal to the count in the standard. It is recommended that this point appear above the center of the calibration curve.

72-73:02G-080
NUMERICAL ANALYSIS OF DRAINAGE OF A HETEROGENEOUS POROUS MEDIUM
Watson, K. K., and Whisler, F. D.
Agricultural Research Service, Phoenix, Arizona, Water Conservation Laboratory.
Soil Science Society of America Proceedings, Vol. 36, No. 2, p 251-256, March-April 1972. 11 fig, 1 tab, 14 ref.

Descriptors: *Soil water movement, *Drainage, *Numerical analysis, Percolation, Mathematical models, Unsaturated flow, Hydraulic conductivity, Seepage, Pressure head.
Identifiers: Gravity drainage.

Gravity drainage of a heterogeneous porous medium was analyzed using a numerical solution of the flow equation. The medium was assumed to exhibit scale heterogeneity, specifically defined in terms of a linear variation of the saturated hydraulic conductivity with depth. Within the restrictions imposed by scale heterogeneity, the hydrologic characteristics were chosen so that their form represented real data. The spatial variation of the hydrologic characteristics was initially defined in terms of the air entry value of the medium and an empirical relationship between the air entry value and the saturated hydraulic conductivity. Pressure head and water content profiles were computed for three hydraulic conductivity distributions in which the conductivity decreased with depth. The pressure head profiles for these distributions show zones of positive pressures and the slow decay of these pressures during drainage.

72-73:02G-081
SOURCE-DETECTOR GEOMETRY EFFECT ON NEUTRON PROBE CALIBRATION,
McCauley, G. N., and Stone, J. F.
Oklahoma State University, Stillwater, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 36, No. 2, p 246-250, March-April, 1972. 3 fig, 6 ref.

Descriptors: *Calibrations, *Nuclear moisture meters, *Instrumentation, *Soil moisture meters, Moisture meters, Nuclear meters, Soil water.
Identifiers: *Neutron detectors.

The midpoint of the anode wire and the center of the sensitive volume of a boron tirfluoride neutron detector tube coincide and should be expected to do so for all such detector tubes of symmetrical construction. The effect of position of the neutron source on the count rate in hydrogenous media was studied. Four hydrogenous media were used: urea, aluminum sulphate, water, and the paraffin shield for the probe. Second-degree curves fit the data of count rate vs. distance between source and reference point. The center of the sensitive volume coincided with the point of greatest count rate. The center was also the position for greatest sensitivity to water content. Changes of source position as small as 0.5 cm from the position at original calibration will significantly change the calibration curve. Users can detect such changes by monitoring ratios of readings in two different hydrogenous media in the laboratory. Any such change in source-detector geometry will produce a change in ratio. Positional changes may be the result of either a source movement or replacement of detector tube with one of different dimension.

72-73:02G-082
SCALING OF HORIZONTAL INFILTRATION INTO HOMOGENEOUS SOILS,
Reichardt, K., Nielsen, D. R., and Biggar, J.W.
California University, Davis, Department of Water Science and Engineering.
Soil Science Society of America Proceedings, Vol. 36, No. 2, p 241-245, March-April 1972. 9 fig, 1 tab, 8 ref.

Descriptors: *Infiltration, *Soil water movement, *Diffusion, Wetting, Hydraulic similitude, Diffusivity, Hydraulic conductivity, Percolation, Soil properties, Porous media, Numerical analysis, Regression analysis.
Identifiers: Similar media.

Horizontal infiltration of water into uniform air-dry soil columns was examined experimentally and theoretically. The applicability of the similar-media concept to the scaling of soils having a wide textural range is studied. The microscopic characteristic length may be determined from plots of the distance to the wetting front as a function of the square root of time. These plots coalasce into one line when expressed in terms of scaled coordinates. If the soil-water diffusivity of one soil is known, values of the microscopic characteristic length can be used to estimate the soil-water diffusivity of the other soils.

72-73:02G-083
APPROXIMATION OF FIELD HYDRAULIC CONDUCTIVITY BY LABORATORY PROCEDURES ON INTACT CORES,
Roulier, M. H., Stolzy, L. H., Letey, J., and Weeks, L. V.
California University, Riverside, Department of Soil Science and Agricultural Engineering.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 387-393, May-June 1972. 7 fig, 1 tab, 17 ref.

Descriptors: *Hydraulic conductivity, *Laboratory tests, *Soil water movement, Computer programs, Sampling, Cores, Unsteady flow, Soil moisture, Unsaturated flow.

Several laboratory procedures for approximating field values of unsaturated hydraulic conductivity over the suction range 30 to 100 cm of water were studied. Conductivity was measured in the laboratory on 10- by 30-cm intact cores by the transient flow (TF) method and was calculated by both the Marshall (M) equation and Millington and Quirk (M and Q) equation using moisture characteristic curves from laboratory measurements on intact cores and from the field data. The TF values were all higher than field values but, when used with a matching factor, they satisfactorily approximated field conductivities. The method of calculating the flow velocity influenced the results. The best results were obtained from a computer program which used a numerical differentiation subroutine. When used with matching factors, conductivities calculated by the M equation and M and Q equation were good approximations of field conductivity, though less satisfactory than results from the TF computer calculations. The best M and Q values were calculated from a field moisture characteristic while the M values were satisfactory when calculated either from the field moisture characteristic or from one measured in the laboratory on intact 6 by 10-cm cores.

72-73:02G-084

SYSTEMATIC AND RANDOM ERRORS IN DUAL GAMMA ENERGY SOIL BULK DENSITY AND WATER CONTENT MEASUREMENTS,

Gardner, W.H., Campbell, G.S., and Calissendorff, C.
Washington State University, Pullman, Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 393-398, May-June 1972. 5 fig, 2 tab, 18 ref.

Descriptors: *Soil density probes, *Soil moisture meters, *Nuclear moisture meters, *Bulk density, Gamma rays, Calibrations, Instrumentation, Nuclear meters, Soil density, Radioactivity techniques.

Soil bulk density and water content may be obtained concurrently through measurement of the attenuation of gamma photons from two different gamma ray sources and simultaneous solution of the resulting attenuation equations. Using gamma photons from Am-241 at 0.060 Mev and from Cs-137 at 0.662 Mev, attenuated in 10-cm soil columns, the standard deviation in both water content and bulk density measurements is primarily due to random emission and is about 0.007 g/cc for 1 million counts measured in air and about 0.005 g/cc for 2.5 million counts. However, as larger counts are used the precision of measurement of column thickness and soil and water attenuation coefficients becomes limiting. Maximum precision is about 0.0035 g/cc at midrange values of water content and bulk density. For narrow collimating slits the spatial resolution is only a little greater than slit thickness.

72-73:02G-085

STEADY INFILTRATION FROM SOURCES AT ARBITRARY DEPTH,

Raats, P. A. C.
Agricultural Research Service, Madison, Wisconsin, Soil and Water Conservation Research Division.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 399-401, May-June 1972. 8 ref.

Steady infiltration is discussed, based on the assumption that the hydraulic conductivity is an exponential function of the pressure head. The solution for infiltration from a single point source at arbitrary depth is presented. On the basis of this solution, a superposition theorem for surface sources is generalized to an arbitrary distribution of sources at arbitrary depths. General expressions for the pressure head, the total head, and the components of the flux are also given.

72-73:02G-086

RELATIVE FLOW RATES OF SALT AND WATER IN SOIL,

Krupp, H. K., Biggar, J. W., and Nielsen, D. R.
California University, Davis, Department of Water Science.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 412-417, May-June 1972. 6 fig, 2 tab, 21 ref.

Descriptors: *Soil water movement, *Ion transport, *Tracers, Salts, Tritium, Chlorides, Dispersion, Mixing, Diffusion, Saline water-freshwater interfaces, Leaching, Translocation, Seepage, Adsorption.
Identifiers: Miscible displacement.

A hydrodynamic equation for the mixing of two miscible solutions in porous media was combined with the Gouy theory for ion distribution in soil pores in order to examine the effect of flow velocity and ion distribution in the pores on the breakthrough curves. The model considers zones of mobile and immobile solution in the porous media, and the extent these zones are affected by the total concentration of the solution and the pore water velocity. Miscible displacement experiments of Cl-36 and tritium through Panoche clay loam at 0.1, 0.01, and 0.001N total salt concentration using CaCl2 were performed on the same column at a fast and slow flow velocity. The exclusion volume for isotope and the separation volume for Cl-36 and tritium increased as flow velocity decreased, and these changes are related to the total ion concentration, the thickness of the diffuse double layer, and the zones of mobile and immobile solution.

72-73:02G-087
SALT AND WATER MOVEMENT IN UNSATURATED FROZEN SOIL
Cary, J. W., and Mayland, H. F.
Agricultural Research Service, Kimberly, Idaho, Snake River Research Center.
Soil Science Society of America Proceedings, Vol. 36, No. 4, p 549-555, July-August 1972. 6 fig, 1 tab, 16 ref.

Descriptors: *Diffusion, *Saline water, *Soil water movement, *Frost heaving, *Frozen soils, Leaching, Ion transport, Mass transfer, Ice, Frost, Freezing, Brines, Salinity, Unsaturated flow.
Identifiers: *Thermal diffusion, *Salt diffusion.

Salt and water movements were measured in unsaturated frozen soil columns incubated under a thermal gradient for 3, 6 or 9 weeks. Both water and salt moved from the warmer to cooler areas in the soil, creating a twofold concentration difference over a 24-cm distance. Movements of CaCl2, Lil, and K2S04 were affected by cation exchange reactions and salt solubilities at high concentrations. Although mass flow of dissolved salts in a liquid film of water was the principal transfer mechanism, both vapor and salt diffusion were sometimes significant. Thermal diffusion and salt sieving did not appear to be important. Because the vapor pressure of ice controls the water potential in frozen soil, the amount of unfrozen water and the matric suction could be calculated from a water release curve and from data of ice suspensions in salt solutions. Mass flow in the liquid phase is described by Darcy's law. Thus, salt flow as well as net water transfer can probably be predicted in unsaturated frozen soil using information available from unfrozen systems.

72-73:02G-088
HYDRAULIC CONDUCTIVITY EVALUATION OF THE SOIL PROFILE FROM SOIL WATER RETENTION RELATIONS,
Bruce, R. R.
Agricultural Research Service, Watkinsville, Georgia, Soil and Water Conservation Research Division.
Soil Science Society of America Proceedings, Vol. 36, No. 4, p 555-561, July-August 1972. 10 fig, 3 tab, 14 ref.

Descriptors: *Hydraulic conductivity, *Soil water movement, *Unsaturated flow, *Moisture content, *Moisture tension, Particle size, Permeability, Percolation, Soil physics, Soil types, Retention.

The water content-suction relation applicable to field soil horizons that differ widely in texture was evaluated. Except for coarse-textured, organic matter-deficient horizons, soil water retention of sieved samples is significantly modified and does not represent the natural soil volume. Water content-suction data from measurements on carefully procured core samples of each horizon of a Typic Hapludult adequately represent their water retention characteristics. Using appropriate water content-suction data, the hydraulic conductivity, water content relation calculated by published procedures was compared with hydraulic conductivity measured on similar samples by a transient outflow procedure. The calculated hydraulic conductivity-water content relations for coarse grained systems or systems having a relatively narrow range of pore size and well-defined bubbling pressure was sufficiently accurate for many porposes. However, to obtain a useful evaluation of the unsaturated hydraulic conductivity of fine-textured horizons with a very wide range of pore size and poorly defined bubbling pressure, the Marshall or Millington and Quirk methods had to be matched at a water content in the 0.1- to 0.3-bar range. Indiscriminate use of such methods of calculating hydraulic conductivity is inadvisable.

72-73:02G-089
SALT DISPERSION COEFFICIENTS NEAR AN EVAPORATING SURFACE,
Todd, R. M., and Kemper, W. D.
Colorado State University, Fort Collins, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 36, No. 4, p 539-543, July-August 1972. 7 fig, 3 tab, 7 ref.

Descriptors: *Dispersion, *Evaporation, *Soil water movement, Ion transport, Diffusion, Mass transfer, Water chemistry, Convection, Salts, Diffusivity, Aqueous solutions.

A series of laboratory experiments was conducted to gain detailed information on water and salt movements near an evaporating surface. Columns instrumented with tensiometers and salinity sensors were used with coarse- and fine-textured soils. Water was supplied to a water table at the base of the columns and approximately steady state evaporation from the soil surface was established. Dispersion coefficients were calculated from salt gradients and evaporation rates in regions of the soil where suctions ranged from 0.1 to several bars. Dispersion increased solution flux and average solution velocity. Values obtained for dispersion coefficients corresponded closely with those obtained under more nearly saturated conditions at similar rates of solution flux.

72-73:02G-090
A NOTE ON A THREE-PARAMETER SOIL-WATER DIFFUSIVITY FUNCTION-APPLICATION TO THE HORIZONTAL INFILTRATION OF WATER,
Parlange, J. Y.
Yale University, New Haven, Connecticut, Department of Engineering and Applied Science.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 318-319, March-April 1973. 2 tab, 5 ref.

Descriptors: *Infiltration, *Diffusivity, *Diffusion, *Soil water movement, Soil moisture, Mathematical studies, Equations.
Identifiers: *Horizontal infiltration.

A realistic water-diffusivity function depending on three parameters described recently by Ahuja and Swartzendruber is solved analitically for the horizontal infiltration of water. The result is expressed in terms of elementary functions and agrees very well with experimental observations.

72-73:02G-091
SOIL WATER FLOWMETERS WITH THERMOCOUPLE OUTPUTS,
Cary, J. W.
Agricultural Research Service, Kimberly, Idaho, Snake River Conservation Research Center.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 176-181, March-April 1973. 7 fig, 1 tab, 8 ref.

Descriptors: *Flowmeters, *Soil water movement, *Water temperature, *Instrumentation, Thermometers, Temperature, Soil temperature, Heat flow, Seepage.
Identifiers: *Thermocouples.

Two soil water flowmeters with thermocouple sensors are described. The meter with a sensitivity of 0.1 mm of waterflow per day is recommended for flux measurements in the surface meter of soil when the water matrix potential is greater than 0.8 bar. Calibration factors for three soils with different textures are presented as a family of curves. These curves may be interpolated for using the flowmeter in other soils, possibly without a loss of accuracy greater than the natural water flow variation from place to place in the field. The meter with a sensivity of about 0.5 mm per day will require some additional development and testing before it can be recommended for routine use. It does offer the possibility of making measurements at soil water matric potentials less than 1 bar and at relatively deep soil depths. The thermocouple flow transducer developed for the meters may be used to measure saturated soil waterflow or other liquid flows as small as 1 ml/day.

72-73:02G-092
DYNAMIC MEASUREMENT OF SOIL AND LEAF WATER POTENTIAL WITH A DOUBLE LOOP PELTIER TYPE THERMOCOUPLE PSYCHROMETER,
Chow, T.L., and De Vries, J.
British Columbia University, Vancouver, Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 181-188, March-April 1973. 11 fig, 14 ref.

Descriptors: *Soil moisture meters, *Water temperature, *Thermometers, Soil temperature, Soil water movement, Calibrations, Temperature, Heat flow, Groundwater potential, Soil-water-plant relationships, Potential flow.
Identifiers: *Psychrometers, *Thermocouples.

Details on the construction, calibration, and performatnce of a three-terminal double loop thermocouple psychrometer are given. The thermal stability of this psychrometer is about 40 times better than that of the two-terminal psychrometer (Spanner type) for ambient temperature fluctuations with a time rate of change greater than 0.2C/min. The response behaviors of a fritted glass bulb and a ceramic bulb psychrometer were tested for vapor and for liquid phase water movement. For vapor phase flow the fritted glass bulb exhibited a shorter response time than the ceramic bulb psychrometer, whereas the reverse was true when water movement was predominantly in the liquid phase. Water potential measurements carried out on silty clay and silt loam soil samples were within plus or minus 0.4 bar of those from the porous plate extractor. A system that facilitates automatic and continuous in situ measurement of soil water potential using the three-terminal psychrometer is described.

72-73:02G-093
HORIZONTAL INFILTRATION OF WATER IN SOILS: A THEORETICAL INTERPRETATION OF

RECENT EXPERIMENTS,
Parlange, J. Y.
Yale University, New Haven, Connecticut, Department of Engineering and Applied Science.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 329-330, March-April 1973. 1 fig, 5 ref.

Descriptors: *Infiltration, *Diffusivity, *Diffusion, *Soil water movement, Soil moisture, Mathematical studies, Equations.
Identifiers: *Horizontal infiltration.

A general theory of water movement is used to describe the horizontal infiltration of water when the diffusivity increases exponentially with moisture content. The results can be expressed in simple analytical form and are in excellent agreement with experimental observations. The results confirm that the theory is accurate because water diffusivity varies with water content.

72-73:02G-094
WATER MOVEMENT AND CALICHE FORMATION IN LAYERED ARID AND SEMIARID SOILS,
Stuart, D. M., and Dixon, R. M.
Nevada University, Reno.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 323-324, March-April 1973.

Descriptors: *Caliche, *Leaching, *Soil formation, Weathering, Calcareous soils, Calcium carbonate, Hardpan, Infiltration, Soil water movement.

In soils, downward water movement is restricted when fine-textured materials are underlain by sand or gravel layers. Water accumulates in arid and semiarid soils at the interface of the fine- and coarse-textured materials and may rarely enter the coarse-textured materials. Calcium carbonate, silica, and other salts are deposited at or near the top of the sand or gravel layers as water is removed by evapotranspiration. With time, silica, calcium carbonates, and other salts become cemented or indurated, forming calcareous crusts at these interfaces. The sands and gravels are not wet uniformly when water does enter, because it enters relatively small areas. Calcareous concentrations may form in these small, wetted areas and may be seen as calcareous cemented columns surrounded by noncalcerous sands or gravels.

72-73:02G-095
ANALYSIS OF MULTIDIMENSIONAL LEACHING,
Peck A. J.
Commonwealth Scientific and Industrial Research Organiztion, Wembley (Australia), Division of Soils.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 320, March-April 1973. 4 ref.

Descriptors: *Leaching, *Infiltration, *Steady flow, Soil water movement, Drainage, Saline water, Equations, Saline soils.

A simplified analysis is given for leaching from the soil surface to tile drains while infiltration is steady and uniform. Leachate concentration is predicted to decay exponentially with characteristics determined by physical parameters of the system. Predicted decay characteristics are in good agreement with Mulqueen and Kirkham's experimental data.

72-73:02G-096
EFFECT OF TEMPERATURE ON PRESSURE HEAD-WATER CONTENT RELATIONSHIP NDUCTIVITY OF TWO SOILS,
Haridasan, M.
Mississippi State University, State College, Department of Agronomy.
PhD Thesis, Mississippi State University Department of Agronomy, August 1971.
66 p, 19 fig, 3 tab, 48 ref.

Descriptors: *Soil water movement, *Soil moisture, *Pressure head, *Temperature, *Hydraulic conductivity, Laboratory tests, Analytical techniques, Soils, Silts, Loam, Saturated soils, Unsaturated flow, Steady flow.
Identifiers: Steady state, Pressure plate outflow.

A series of experiments was conducted in the laboratory to study the effect of temperature on the pressure head-water content relationship and the hydraulic conductivity as a function of water content and pressure head in two soils. Hydraulic conductivity of two silt loams were determined as a function of water content and pressure head at constant temperatures of 15, 25, and 35 deg C by steady state and pressure plate outflow methods. The pressure head at a given water content increased as the temperature increased. The maximum changes were observed in the region of inflection of the desorption curves. The water content at a given pressure head decreased with a rise in temperature. Conductivity of the soils at saturation increased as the temperature increased and conductivity of unsaturated soils at a given water content increased with a rise in temperature. The pressure plate outflow method seemed to be more suitable for laboratory determination of hydraulic conductivity of unsaturated soils than the steady-state method. Data obtained by the pressure plate outflow method were more consistent and required considerably less time to obtain conductivity as a function of soil water content.

72-73:02G-097
FIELD MEASUREMENT OF UNSATURATED HYDRAULIC CONDUCTIVITY BY INFILTRATION THROUGH GYPSUM CRUSTS,
Bouma, J., and Denning, J. L.
Wisconsin Geological and Natural History Survey, Madison.
Soil Science Society of America Proceedings, Vol. 36, No. 5, p 846-847, September-October 1972. 2 fig, 3 ref.

Descriptors: *Infiltration, *On-site tests, *Unsaturated flow, *Hydraulic conductivity, Soil water movement, Gypsum, Steady flow.
Identifiers: *Soil crusts.

Field trials were made to test the use of gypsum crusts in the crust test method for measuring unsaturated hydraulic conductivity (K) in situ. Crust consisting of mixtures of sand and gypsum were more stable and had more constant hydraulic properties than previously used crusts consisting of various puddled soil materials. Test results of four soil horizons are reported.

72-73:02G-098
TRANSFORMATION OF MANGANESE IN A WATERLOGGED SOIL AS AFFECTED BY REDOX POTENTIAL AND PH,
Gotoh, S., and Patrick, W. H., Jr.
Louisiana State University, Baton Rouge, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 36, No. 5, p 738-742, September-October 1972. 4 fig, 24 ref.

Descriptors: *Manganese, *Soil chemistry, *Anaerobic conditions, *Oxidation-reduction potential, *Solubility, *Hydrogen ion concentration, Oxidation, Reduction (Chemical), Trace elements, Nutrients, Ion exchange.
Identifiers: *Soil manganese.

The distribution of different forms of manganese in waterlogged soil was studied over a wide range of closely controlled Eh-pH conditions. At pH 5 almost all of soil manganese was converted from the reducible to the water-soluble plus exchangeable fraction even at a redox potential as high as +500 mV. In sharp contrast, at pH levels between 6 and 8 most of the conversion took place at relatively lower redox potentials of +200 to +300 mV. When the water-soluble plus exchangeable fraction was further divided into its two components, low pH and low Eh increased water-soluble manganese at the expense of the exchangeable form. Cation exchange reactions were important in regulating the equilibria between water soluble and exchangeable manganese. Labeled manganese added to the soil showed an almost identical distribution among the various manganese fractions to that of native soil manganese. The observed pMn/pH slope and Eo were much lower at pH 6 to 8 than those calculated for pure equilibrium systems. The Eh and pH of flooded soils provide general control of manganese transformation, which probably includes both chemical and biological processes.

72-73:02G-099
THE TRANSPORT OF CATIONS IN SOIL COLUMNS AT DIFFERENT PORE VELOCITIES,
Lai, S. H., and Jurinak, J. J.
Utah State University, Logan, Department of Soil Science and Biometeorology.
Soil Science Society of America Proceedings, Vol. 36, No. 5, p 730-733, September-October 1972. 5 fig, 2 tab, 14 ref.

Descriptors: *Ion transport, *Pore water, *Soil water movement, *Ion exchange, Cation exchange, Adsorption, Leaching, Translocation, Clays.
Identifiers: *Cation transport (Soils).

The transport of Na and Mg in Ca-saturated Yolo loam soil column under saturated steady state flow of different pore velocities was studied. The cation solution was maintained at a concentration such that a linear adsorption isotherm described the cation adsorption. Experimental retention curves were compared to the theoretical solutions obtained from a linear equilibrium model. At low relative concentrations, the equilibrium adsorption of Na was significantly less than that of Mg. At high pore velocities, the agreement of the experimental retention curves with that of the theoretical calculation was good. At low pore velocity, the agreement was poor. The retention volumes of Na and Mg were smaller than those theoretically calculated and those obtained experimentally at high pore velocity. Extensive tailing of Mg observed in the experimental data was not described by the theoretical model.

72-73:02G-100
THE EFFECT OF BULK DENSITY AND INITIAL WATER CONTENT ON INFILTRATION IN CLAY SOIL SAMPLES,
Gumbs, F. A., and Warkentin, B. P.
Macdonald College, Montreal (Quebec), Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 36, No. 5, p 720-724, September-October, 1972. 6 fig, 2 tab, 16 ref.

Descriptors: *Infiltration, *Expansive clays, *Expansive soil, *Bulk density, Diffusivity, Moisture content, Clays, Absorption, Adsorption, Soil water movement.

Infiltration measurements were made on swelling clay soil samples packed into columns. Small increases in bulk density over the range 1.10 to 1.25 g/cc markedly decreased the rate of water movement. The magnitude of the effect was greater for confined samples than unconfined samples at all initial water contents. A 1-cm compact layer in the profile retarded water movement if the soil was confined. In partially confined samples the soil in the compact layer would swell on wetting, and water movement was retarded only when the bulk density after swelling still exceeded the bulk density of the remainder of the column. Bulk densities below 1.05 g/cc, and heat of wetting in partially confined samples with 0% initial water content produced nonlinear relationships of distance to wet front vs. square root of time. Under these experimental conditions gravity contributed significantly to water movement at high initial water content.

72-73:02G-101

NITROGEN, SALINITY, AND ACIDITY DISTRIBUTION IN AN IRRIGATED ORCHARD SOIL AS AFFECTED BY PLACEMENT OF NITROGEN FERTILIZERS,

Felizardo, B. C., Benson, N. R., and Cheng, H. H.
Philippines University, College, Laguna, Philippines.
Soil Science Society of America Proceedings, Vol. 36, No. 5, p 803-808, September-October, 1972. 6 fig, 2 tab, 13 ref.

Descriptors: *Nutrient removal, *Leaching, *Fertilizers, Nitrogen, Salinity, Acidity, Fertilization, Application methods, Drainage effects, Environmental effects.

A field experiment was conducted to determine the vertical and lateral changes in the distribution of nitrogen, salinity, and acidity occurring in an irrigated orchard soil following addition of $(NH_4)_2SO_4$, NH_4NO_3, or $Ca(NO_3)_2$ by broadcast, in broad band, or in narrow band. The NH_4 and NO_3 contents in soil decreased rapidly even under narrow band placements. Considerable nitrate movement was observed. After 1 year, neither the total nor the inorganic N level in the fertilized plots was significantly different from that of the control. High salinity was detected under the narrow band placements, but the level diminished rapidly with time. Little salinity was evident under the broad band or broadcast placements. However, the acidity produced by the ammonium fertilizers persisted after 1 year. Changes in soil properties under narrow bands were drastic, whereas changes under broad bands were insignificant.

72-73:02G-102

MEASUREMENT OF THE DIFFUSION COEFFICIENT OF BORON IN SOIL USING A SINGLE CELL TECHNIQUE,

Sulaiman, W. and Kay, B. D.
College of Agriculture, Malaya, Sungai Basi, Selangor, Malaysia.
Soil Science Society of America Proceedings, Vol. 36, No. 5, p 746-752, September-October, 1972. 5 fig, 3 tab, 20 ref.

Descriptors: *Nutrient removal, *Boron, *Trace elements, Nutrients, Diffusion, Soil chemistry, Soil physics, Soil water.

The porous system diffusion coefficient, Dp, or boron in a loam soil was measured by means of a single cell technique. Boron diffused from a semi-infinite medium of uniform initial concentration to a sink of constant concentration which was separated from the soil by a dialysis membrane. A polyethylene glycol 6,000 solution circulated through the sink and controlled the soil matric suction osmotically. The diffusive flux at the soil and membrane interface was treated as an evaporative process. The value of Dp was found to be 2.44 ± 0.00000017 sq. cm/sec. when the bulk density of the soil and the volumetric moisture content were 1.30 gm/cm3 and 0.31, respectively. The significance of the equilibria between absorbed and solution B on the diffusion rate of B was also studied. Addition to the soil of boric acid solutions of concentrations lower than 1 ppm resulted in a capacity factor and solution B concentration which were lower than the corresponding values when water containing no B was added. As a consequence, the quantity of B diffusing into the sink from the boron-treated soil was less than that from the untreated soil.

72-73:02G-103
MANGANESE AND IRON SOLUBILITY CHANGES AS A FACTOR IN TILE DRAIN CLOGGING:
II. OBSERVATIONS DURING THE GROWTH OF COTTON,
Grass, L. B., MacKenzie, A. J., Meek, B. D., and Spencer, W. F.
Imperial Valley Conservation Research Center, Brawley, California.
Soil Science Society of America Proceedings, Vol. 37, No. 1, p 17-21, January-February, 1973. 8 fig, 2 tab, 8 ref.

Descriptors: *Salinity, *Leaching, Manganese, Iron, Drainage, Subsurface drainage, Tile drainage, Nitrates, Anaerobic conditions, Aerobic conditions.

Various levels of oxidation-reduction develop in the soil profile during the irrigation and growing season of the cotton crop. Reducing intensity increased with depth during the growing season and reached maximum intensity at the 6.10-m depth. Reducing conditions favorable to increased solubility of Fe and Mn were observed in the surface horizons of the profile during most of the season. Changes in the solubility of manganese and iron occurred with changes in the oxidation-reduction status in the soil profile. Manganese began to dissolve at 400 mV and became significant at less than 300 mV. Increased concentration of nitrate retarded reduction of oxidized Fe and Mn compounds. The salinity of the soil solution affected the concentration of soluble manganese and iron. The presence of NO3-N in the soil solution in amounts less than 0.2 ppm retarded the dissolution of Mn compounds. The solubility of manganese and iron can probably be controlled by controlling or regulating the oxidation-reduction status of the soil profile by reducing the waterlogging period after irrigation to a minimum.

72-73:02G-104
COINCIDENCE AND INTERFERENCE CORRECTIONS FOR DUAL-ENERGY GAMMA RAY MEASUREMENTS OF SOIL DENSITY AND WATER CONTENT,
Mansell, R. S., Hammond, L. C., and McCurdy, R. M.
Florida University, Gainesville, Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 500-504, July-August 1973. 3 fig, 2 tab, 11 ref.

Descriptors: *Nuclear moisture meters, *Soil moisture meters, *Gamma rays, Bulk density, Soil water, Calibrations, Instrumentation.
Identifiers: Gamma-ray spectrometers.

Volumetric water content and bulk density changes in a soil column can be simultaneously and rapidly determined from single-detector attenuation measurements of a high intensity, dual-energy beam of gamma photons. Coincidence loss due to interference between the two monoenergetic gamma rays and Compton scattering provides gamma photon intensities which are undesirably interdependent. Correction procedures are given for providing independent determinations of both 60 and 662 keV gamma ray intensities.

72-73:02G-105
MANGANESE AND IRON SOLUBILITY CHANGES AS A FACTOR IN TILE DRAIN CLOGGING: I. OBSERVATIONS DURING FLOODING AND DRYING,
Grass, L. B., MacKenzie, A. J., Meek, B. D., and Spencer, W. F.
Imperial Valley Conservation Research Center, Brawley, California.
Soil Science Society of America Proceedings, Vol. 37, No. 1, p 14-17, January-February, 1973. 5 fig, 1 tab, 27 ref.

Descriptors: *Salinity, *Leaching, Manganese, Iron, Drainage, Subsurface drainage, Tile drainage, Nitrates, Anaerobic conditions, Aerobic conditions.

A field study of waterlogging and subsequent drying of the soil profile has shown that under irrigation culture in Imperial Valley reducing conditions became prevalent. Reducing conditions, as indicated by declining Eh values, became most favorable for dissolution of Mn and Fe near the soil surface. However, the concentrations of Mn2 and Fe2 were lowest near the surface, probably because of their leaching from this zone, and the shorter time of contact between soil solution and soil particles. The concentration of Fe2 and Mn2 were higher in the deeper horizons of the soil profile. In the plow layer, the reducing intensity increased, beginning 9 m away from the tile and reaching a maximum 18- to 23-cm from the tile drain. The Eh levels in the soil profile declined immediately after irrigation began and rose immediately after irrigation stopped indicating the importance of atmospheric oxygen to the oxidation-reduction status and, therefore, to the solubility of iron and manganese compounds. Soluble organic carbon apparently was not related to the concentration of Mn2 and in the soil solution even though the decomposition of soil organic matter is important in oxidation-reduction reactions in the soil profile.

72-73:02G-106
NITRATE CONCENTRATIONS IN THE UNSATURATED ZONE BENEATH IRRIGATED FIELDS IN SOUTHERN CALIFORNIA,
Pratt, P. F., and Adriano, D. C.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 321-322, March-April, 1973. 1 fig, 1 tab, 5 ref.

Descriptors: *Drainage, *Nutrient removal, Nitrogen, Leaching, Denitrification, Nitrates, Crop response, Crop production.

Nitrate concentrations in the drainage water of the unsaturated zone beneath the soil-root zone were predicted from data for N inputs, N removal in harvested crops, and the drainage volume. Ratios of these predicted values to measured values were related to the volatilization losses or unaccounted-for inputs expressed as a fraction of the excess N defined as the N input minus N removal in harvested crops. Volatilization losses or unaccounted-for inputs were calculated as known inputs minus removal in harvested crops minus that removed from the soil-root system by leaching.

72-73:02G-107
EFFECTS OF STRAW, CALCIUM CHLORIDE, AND SUBMERGENCE ON A SODIC SOIL,
Puttaswamygowda, B. S., and Pratt, P. F.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 208-212, March-April, 1973. 5 fig, 3 tab, 15 ref.

Descriptors: *Saline soils, *Alkali Soils, Salinity, Leaching, Reduction (chemical), Soil chemistry, Soil physics, Organic matter, Anaerobic conditions, Aerobic conditions.

The effects of straw and CaCl2 during 130 days of submergence, and the effects of these amendments under submerged aerobic vs. anaerobic conditions for a period of 30 days were studied. Comparisons of pH, EC, Na, Ca + Mg, K, Fe, the optical density of the water extract, and ESP were used to evaluate the effects of these amendments. The straw and straw + CaCl2 treatments had the largest effect in lowering the pH and the ESP, increasing the Na and Ca + Mg concentrations and the EC. Submerged anaerobic conditions had the largest effect on promoting these reactions. The concentrations of Fe2 was highest in the straw treatments whereas CaCl2 had a depressing effect on the soluble Fe2. The optical density was lowest in the straw plus CaCl2 amendment treated soil and the effect of this treatment was larger under anaerobic conditions. Wheat straw under anaerobic conditions caused an increase in the sum of Na plus Ca plus Mg that was about three times greater than the sum of these cations in the straw itself. In combination with CaCl2 wheat straw reduced the loss of Ca from solution observed when CaCl2 alone was added to soil.

72-73:02G-108
AN OSCILLATOR CIRCUIT FOR AUTOMATED SALINITY SENSOR MEASUREMENTS,
Austin, R. S., and Oster, J. D.
United States Salinity Laboratory, Riverside, California.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 327-329, March-April, 1973. 3 fig, 1 tab, 10 ref.

Descriptors: *Salinity, Electric conductance, Specific conductivity, Soil chemistry, Water chemistry, Saline soils.

An oscillator circuit is described that enables automatic reading of salinity sensors and other a.c. conductivity cells by measuring frequency of oscillation. The oscillator frequency varies between 0.13 to 30 KHz and changes linearly with conductance in the range of 0.03 to 10 mmho/cm. The temperature sensitivity of the frequency of the oscillator is negligible between 8 and 31 C. The calibration curves between frequency and conductance obtained with the oscillator circuit for both the electrical conductivity and thermistor elements of the salinity sensor are linear and readings can be obtained with lead lengths of several hundred meters.

72-73:02G-109
FLOOD AND SEEPAGE WATER SAMPLING TECHNIQUES, IN RICE FIELDS UNDER DIFFERENT WATER MANAGEMENT PRACTICES,
Tanji, K. K., Biggar, J. W., Mehran, M., and Henderson, D. W.
California University, Department of Water Science and Engineering, Davis.
Soil Science Society of America Proceedings, Vol. 37, No. 3, p 483-485, May-June, 1973. 3 fig, 1 tab.

Descriptors: *Water pollution sources, *Nutrient removal, Leaching, Water sampling, Rice, Flooding, Seepage.

Sampling equipment reported herein enables collection of flood and seepage waters to determine persistance and transport of chemicals applied in flooded rice culture. This system gives a capability of cultivating the effects of different chemical application methods (Water-applied, soil-incorporated) and water management systems (static, flow-through, and recycled).

72-73:02G-110
MODEL FOR ESTIMATING SOIL WATER, PLANT, AND ATMOSPHERIC INTERRELATIONS: I. DESCRIPTION AND SENSITIVITY,
Nimah, M. N., and Hanks, R. J.
Utah State University, Utah Water Research Laboratory, Logan.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 522-527, July-August, 1973. 11 fig, 3 tab, 16 ref.

Descriptors: *Drainage, *Soil-water-plant relationships, *Soil water, Evapotranspiration, Computer models, Root systems, Soil water movement.

A model and its numerical solution were developed to predict water content profiles, evapotranspiration, water flow from or to the water table, root extraction, and root water potential under transient field conditions. Soil properties needed are hydraulic conductivity and soil water potential as functions of water content. Plant properties needed are rooting depth and limiting root water potential. Climatic properties needed are potential evaporation and potential transpiration. The model predicted significant changes in root extraction, evapotranspiration, and drainage due to the variations in pressure head-water content relations and root depth. Variations in the limiting root water potential had a small influence on estimated evapotranspiration, drainage, and root extraction.

72-73:02G-111
MODEL FOR ESTIMATING SOIL WATER, PLANT, AND ATMOSPHERIC INTERRELATIONS: II. FIELD TEST OF MODEL,
Nimah, M. N., and Hanks, R. J.
Utah State University, Utah Water Research Laboratory, Logan.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 528-532, July-August, 1973. 11 fig, 1 tab, 7 ref.

Descriptors: *Drainage, *Soil-water-plant relationships, *Soil water, Evapotranspiration, Computer models, Root systems, Soil water movement.

A mathematical model was developed to predict water content profiles, evapotranspiration, water flow from or to the water table, root extraction, and root water potential at the surface under transient conditions. The model was field tested in 1970 and 1971. With alfalfa as the crop, predicted and computed water content-depth profiles show best agreement 48 hours after any water addition. The poorest agreement for all crops tested was right after irrigation. The computed cumulative upward water flow from the water table was 4.80 cm as compared to 0.6 cm measured for the whole 1971 season of 116 days.

72-73:02G-112
EFFECTS OF DRAINAGE AND ORGANIC AMENDMENTS ON THE RECLAMATION OF A SODIC SOIL CROPPED WITH RICE,
Puttaswamygowda, B. S., Wallihan, E. F., and Pratt, P. F.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 621-625, July-August, 1973. 6 fig, 3 tab, 22 ref.

Descriptors: *Salinity, *Sodium, *Alkaline soils, Soil chemistry, Organic matter, Drainage, Soil physics.

In a greenhouse pot culture study, effects of drainage and organic amendments on the reclamation of a saline sodic soil material under submerged conditions were studied with and without the presence of a rice crop. In drained soils, application of dairy manure, sugar, straw or straw + $CaCl_2$ increased the rate of drainage and decreased the electric conductivity and exchangeable sodium percentage. Without drainage, treatments were less effective. Crop growth hastened the reclamation process by increasing the volume of water drained and the concentration of Ca + Mg in the drainage water. Drainage had a significant effect on the vegetative growth of rice, percentage of earbearing tillers, and straw and grain yield. In the undrained condition, organic soil amendments, except dairy manure, adversely affected the straw and grain yield.

72-73:02G-113
CONTROLLED INSTANTANEOUS APPLICATION OF FREE WATER TO A POROUS SURFACE,
Swartzendruber, D., and Asseed, M. S.
Purdue University, West Lafayette, Indiana.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 967-968, November-December, 1973. 1 fig.
(See 72-73:04A-034)

72-73:02G-114
VACUUM EXTRACTORS TO ASSESS DEEP PERCOLATION LOSSES AND CHEMICAL CONSTITUENTS OF SOIL WATER,
Duke, H. R., and Haise, H. R.
United States Department of Agriculture, Agricultural Research Service, Fort Collins, Colorado.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 963-064, November-December, 1973. 3 fig.

Descriptors: *Soil water, *Drainage effects, Infiltration, Percolation, Soil water movement, Leaching, Water quality.

A vacuum extractor, consisting of a porous ceramic tube within a sheet-metal trough, has been developed to provide a quantitative measure of soil water lost by deep percolation and to provide a water sample for chemical analysis. Several of these extractors have been installed in the field and preliminary field performance is reported. Detailed laboratory evaluation is in progress.

72-73:02G-115
A NEW APPROACH TO SOIL TESTING: II. IONIC EQUILIBRIA INVOLVING H, K, Ca, Mg, Mn, Fe, Cu, Zn, Na, P, and S,
Baker, D. E.

Pennsylvania Agricultural Experiment Station, University Park.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 537-541, July-August, 1973. 6 tab, 24 ref.

Descriptors: *Soil chemistry, *Ions, *Soil tests, Salinity, Soil analysis, Soil investigations, Soil properties, Soil science.

Several experiments were conducted in an effort to modify a new approach to soil testing in which the equilibrating or testing solution contains each element for which the soil is being tested. This report includes results for modification which caused 15 soils to differ more with respect to test levels of Mn, Fe, Zn, Cu, S, and P without substantially changing their rankings for K, Ca, and Mg. Modifications included the incorporation of a preservative, a flocculating agent, a pH buffer, DTPA, and several additional elements to maintain a relatively constant activity coefficient for each element in different soils. Results concluded that the adsorption equilibria soil test can be used successfully to test for several elements. The approach for calculating soil requirements is given for P. Although the test shows promise by indicating soil differences, additional calibration data will be required prior to routine use of the method.

72-73:02G-116
PRINCIPLES OF MANAGING HIGH FREQUENCY IRRIGATION,
Rawlins, S. L.
United States Salinity Laboratory, Riverside, California.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 626-629, July-August, 1973. 3 fig, 6 ref.

Descriptors: *Irrigation practices, *Irrigation, Irrigation systems, Irrigation design, Sprinkler irrigation, Soil physics, Soil science.

The consequences of increasing irrigation frequency are explored, taking into consideration the laws governing water flow in soil. As frequency increases, the waterholding capacity of the soil becomes less important because water is supplied as the plants require it. Soil water content, and therefore matric potential, are continuously high and only slightly dependent upon deep percolation rate. This makes the need for deep percolation to leach salts the only valid criterion for applying more water than the plants transpire. The need to apply extra water to those crops that require high soil water content is eliminated. Controlling the deep percolation rate rather than water potential as inputs for managing the quantity of water to be applied.

72-73:02G-117
RESPONSE OF SALINITY SENSORS TO RAPIDLY CHANGING SALINITY,
Wesseling, J., and Oster, J. D.
Agricultural Research Service, Riverside, California, Salinity Laboratory.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 553-557, July-August 1973. 5 fig, 3 tab, 12 ref.

Descriptors: *Salinity, *Electrical conductance, *Instrumentation, Calibrations, Water chemistry, Diffusion, Diffusivity.
Identifiers: *Soil salinity meters.

A theory developed to describe the response of the sensor to changes in soil salinity is based on the assumption that diffusion of solutes into and out of the sensitive element of a salinity sensor determines its response time. This theory was experimentally verified in solution and in soils. The response of a sensor is adequately described by a single response factor. Proper use of this factor permits the actual electrical conductivity of the soil solution to be inferred from sensor readings where soil salinity changes rapidly.

72-73:02G-118
A STUDY OF THE UNIQUENESS OF THE SOIL MOISTURE CHARACTERISTIC DURING DESORPTION BY VERTICAL DRAINAGE,
Vachaud, G., Vauolin, M. and Wakil, M.
Universite Scientifique et Medicalede Grenoble, Laboratoiries de Mecanique des Fluides, Grenoble, France.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 531-532, May-June, 1972. 2 fig, 6 ref.

Descriptors: *Soil water, *Drainage, Transition flow, Tensiometers, Soil moisture.

Previous experiments concerning the desorption of a horizontal column of uniform soil suggested that the moisture characteristic was not unique throughout the column. Further desorption experiments have been carried out on a vertical column. The results are consistent with those obtained previously, and give further information on the dual dependence of Psi on Theta and on partial derivative of Psi over the partial derivative of t.

72-73:02G-119
NITROGEN MINERALIZATION POTENTIALS OF SOILS,
Stanford, G., and Smith, S. J.
United States Soils Laboratory, Beltsville, Maryland.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 465-472, May-June, 1972. 2 fig, 5 tab, 16 ref.

Descriptors: *Nutrient removal, *Nitrogen, Leaching, Nigrogen fixation, Incubation.

Net mineralization of N in 39 widely differing soils was determined over a 30-week period at 35C, using incubation intervals of 2, 2, 4, 4, 4, 6, and 8 weeks. Mineral N was leached from the soils before the first incubation and following each of seven incubations by means of 0.01M CaCl2 and a minus-N nutrient solution. Soil water contents were adjusted by applying suction, and losses of water during incubation under aerobic conditions were negligible. With most soils, cumulative net N mineralized was linearly related to the square root of time. The pH of soils changed very little in the course of 30 weeks' incubation. Because of the generally consistent results, the data were employed in calculating the N mineralization potential, No, of each soil, based on the hypothesis that rate of N mineralization was proportional to the quantity of N comprising the mineralizable substrate. Values of No ranged from about 20 to over 300 ppm of air-dry soil. The fraction of total N comprising No varied widely among soils. Mineralization rate constants did not differ significantly among most of the soils.

72-73:02G-120
COLORIMETRIC, SEMIQUANTITATIVE TEST FOR SOIL SALINITY,

Bower, C. A.
United States Salinity Laboratory, Riverside, California.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 527-528, May-June, 1972. 2 tab.

Descriptors: *Salinity, *Measurement.
Identifiers: Field test

A colorimetric, semiquantitative test for soil salinity is described based on the equivalent release of yellow CrO4 ion upon reaction of Cl and SO4 with slightly soluble Ag2CrO4 and SrCrO4, respectively, to form less soluble AgCl and SrSO4.

72-73:02G-121
FURTHER EVIDENCE FOR THE INABILITY OF THE KJELDAHL TOTAL NITROGEN METHOD TO FULLY MEASURE INDIGENOUS FIXED AMMONIUM NITROGEN IN SUBSOILS,
Meints, V. W., and Peterson, G. A.
Nebraska Agricultural Experiment Station, Lincoln.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 434-436, May-June, 1972. 2 tab, 6 ref.

Descriptors: *Fertility, *Nutrients, Nitrogen, Soil chemical properties, Subsoil, Nitrates.

Three methods of Kjeldahl total N determinations in soils were compared. Method 1 involved a pretreatment of the soil with a HF-acid mixture and resulted in higher N values than methods 2 or 3 which involved a long period of digestion and a modification of a Gunning method, respectively. Differences in total N values obtained by the three methods were greatest for subsoils. The inability of methods 2 and 3 to measure all of the indigenous fixed NH4+-N resulted in low N values and erroneously high C:N ratios in the subsoil.

72-73:02G-122
INTERACTION EFFECTS OF BORON AND LIME ON BARLEY,
Gupta, U. C.
Canada Department of Agriculture, Research Station, Charlottetown, Prince Edward, Island.
Soil Science Society of America Proceedings, Vol. 36, No. 2, p 332-334, March-April, 1972. 3 tab, 15 ref.

Descriptors: *Nutrient requirements, *Trace elements, *Boron, Toxicity, Crop response, Barley, Salts, Salinity.

A greenhouse study involving six levels of B and four levels of lime was conducted on barley. Boron toxicity symptoms occurred at 0.5 to 4.0 ppm applied B, with the most severe symptoms occurring at 4.0 ppm B level at soil pH 5.3. At 0.5 ppm B, no visible symptoms occurred at pH values of 6.3 and 6.8, and at 1.0 ppm B no symptoms occurred at pH 6.8. There was a highly significant soil pH x B interaction, in which high rates of B were more detrimental to kernel yields at lower pH than at high pH values. The highest kernel yields were recorded with 0.25 ppm B at soil pH 5.8. An application of 4.0 ppm B at soil pH 5.3 and 5.8 did not produce any kernels. A range in the B concentration of 1.4 to 9.9 ppm and in Ca/B ratio of 343 to 1,159 in the b.s.t. collected from Prince Edward Island fields indicated a deficiency of B in many soils for growing barley. However, no visible B deficiency symptoms were found either under greenhouse or field conditions.

72-73:02G-123
CALCIUM-MAGNESIUM-POTASSIUM EQUILIBRIA IN SOME CALIFORNIA SOILS,
Carlson, R. M., and Buchanan, J. R.
California University, Department of Pomology, Davis.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 851-855,
November-December, 1973. 5 fig, 3 tab, 19 ref.

Descriptors: *Salinity, *Ion exchange, Ions, Leaching, Fertilizers, Potassium, Nutrient removal, Equilibrium.

Ion exchange equilibria in several soils were studied to seek equilibrium equations that could be used in chromatographic models dealing with movement and distribution of fertilizer potassium in soil profiles. Soil samples were equilibrated with mixtures of CaCl2, MgCl2, and KCl solutions and then extracted with NH4OAc to determine exchangeable cation compositions at equilibrium. It was necessary to correct the exchangeable cation concentrations by subtracting the cations extracted from nonexchangeable sources by NH4OAc. Vanselow's, Davis', Gapon's or Kerr's equation would not decribe the equilibria. Equations were developed to describe the equilibria.

72-73:02G-124
THE SIMULTANEOUS EFFECT OF pH AND CHLORIDE CONCENTRATIONS UPON MERCURY (II) AS A POLLUTANT,
Hahne, H. C. H. and Kroontje, W.
Virginia Polytechnic Institute and State University, Blacksburg.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 838-843,
November-December, 1973. 8 fig, 2 tab, 25 ref.

Descriptors: *Mercury, Pollutants, Salinity, Water quality, Water pollution sources.

The mercuric ion, compared to other heavy metal pollutants, hydrolyzes at low pH values and forms soluble chloride complexes at low chloride concentrations. To evaluate the possible implications of such behavior in natural aquatic systems, Hg(II) hydroxy and chloride species distributions were calculated using pH and chloride ion concentrations as variables simultaneously. Range in pH values selected was from 2 to 9 to cover conditions encountered in acid mine drainages, rivers, all types of soil solution extracts, and sea-water. In addition, a study was performed in which montmorillonite, illite, and kaolinite were equilibrated with different HgCl2 solutions. The range of HgCl2 concentrations in equilibrium solutions was 1.25 x 10-4M tc 0.005M. Results of the calculations show that chloride complexes compete effectively with the hydroxy complexes of Hg(II).

72-73:02G-125
THE EFFECT OF EXCLUSION VOLUME ON POTENTIOMETRIC NITRATE MEASUREMENTS,
Gilmour, J. T., and Scott, H. D.
Arkansas University, Agronomy Department, Fayetteville.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 959-960,
November-December, 1973. 1 fig, 2 tab, 10 ref.

Descriptors: Nitrates,Nitrogen, Clays,Montmorillonite.

Data are presented which show that large anion exclusion volumes can occur when montmorillonitic soils, low in total salt, are extracted with water. Nitrate measurements on such extracts with the nitrate specific ion electrode reflect this exclusion volume induced error. A possible solution to the problem is suggested.

72-73:02G-126
TEST OF A NEW MODEL FOR THE KINETICS OF ADSORPTION-DESORPTION PROCESSES,
Griffin, R. A., and Jurinak, J. J.
Utah State University, Logan.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 869-872,
November-December, 1973. 5 fig, 1 tab, 8 ref.

Descriptors: *Nutrient removal, Phosphates, Adsorption, Thermodynamics, Mathematical models, Computer models.

A new model for the kinetics of adsorption-desorption processes proposed by Lindstrom, Haque, and Coshow (1970) was tested with adsorption and desorption data for the interaction of phosphate with the calcite mineral surface. The model was found to offer considerable advantages in speed and convenience to those users whose experimental conditions correspond to the assumptions inherent in the derivation of the model. There was reasonable agreement between the predicted adsorption kinetic parameters and experimental data. However, considerable disparity was observed between predicted and experimental desorption parameters. It was concluded that the model was not valid for endothermic processes.

72-73:02G-127
SOLUTION AND ADSORBED FLUOMETURON CONCENTRATION DISTRIBUTION IN A WATER-SATURATED SOIL: EXPERIMENTAL AND PREDICTED EVALUATION,
Hornsby, A. G., and Davidson, J. M.
United States Environmental Protection Agency, Ada, Oklahoma.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 823-828,
November-December, 1973. 7 fig, 2 tab, 12 ref.

Descriptors: Adsorption, Solutes, Soil water, Soil moisture, Salinity.
Identifiers: Desorption, Miscible displacement, Dispersion coefficient, Solute transport model.

A technique is described for measuring the solution and adsorbed phases of fluometuron in water-saturated soil columns. The data reveal that at an average pore-water velocity of 5.5 cm/hour, the solution and adsorbed phases of fluometuron are not in equilibrium, whereas, at the 0.59 cm/hour velocity they were in equilibrium. The kinetic rate equations for adsorption and desorption were not significantly better than the equilibrium model when describing the fast displacement of fluometuron through soils. The desorption distribution coefficient was found to be a function of the maximum amount of herbicide adsorbed prior to desorption. The experimental data were reasonably well described by the mathematical model.

72-73:02G-128
UNSTEADY TWO-DIMENSIONAL FLOW OF WATER IN UNSATURATED SOILS ABOVE AN IMPERVIOUS BARRIER,
Selim, H. M., and Kirkham, D.

Iowa State University, Ames, Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 489-495, July-August 1973. 6 fig, 20 ref.

Descriptors: *Soil water movement, *Wetting, *Unsaturated flow, *Aquicludes, Unsteady flow, Ditches, Numerical analysis, Drainage systems.

The equation describing unsteady two-dimensional water flow in unsaturated soils may be solved by use of a finite difference approximation and an alternating-direction implicity method. The two-dimensional medium is a homogeneous soil with an impervious barrier at some depth from the soil surface and having equally spaced trenches. The bottoms of the trenches are wetted at time zero and are kept at a constant 0.50 water content. The initial soil water content is 0.20. Water movement from the walls of the trenches and the soil surface is neglected. The water content at all locations in the flow medium was obtained for an Ida silt loam soil with two geometries. Near trenches with 120-cm spacing, 30-cm deep, and 30-cm wide, the wetting front reaches a depth of 30 cm in 35 min, and reaches the soil surface in 140 min. Near trenches with 60-cm spacing, 15-cm deep, and 15-cm wide, the wetting front reaches a depth of 30 cm in 45 min, and reaches the soil surface in 30 min.

72-73:02G-129

CULTURAL PRACTICES FOR IRRIGATED WINTER WHEAT PRODUCTION,

Unger, P. W., Allen, R. R., and Parker, J. J.
United States Department of Agriculture, Southwestern Great Plains Research Center, Bushland, Texas.
Soil Science Society of America Proceedings, Vol. 37, No. 3, p 437-442, May-June, 1973. 5 tab, 21 ref.

Descriptors: *Cultivation, *Irrigation, Infiltration, Water use, Efficiencies, Organic matter, Nitrogen, Bulk density, Wheat.

Rototilling, moldboard plowing, disking, burn-listing, and listing were satisfactory tillage methods for managing the residues produced by continuous irrigated winter wheat. Grain yields averaged highest for moldboard plowing and lowest for lister plowing. Nitrogen fertilizer at 90 or 135 kg N/ha resulted in significant grain and residue yield differences in a few years, but no consistent trends were apparent. Irrigation water infiltration was highest for moldboard plowing and lowest for lister plowing. The list and burn-list treatments resulted in similar infiltration. Water-use efficiencies were similar for all treatments. At the end of the 5-year study, soil organic matter content was lowest (1.66%) for burn-lister tillage and highest (1.72%) for lister and disk tillage. Water-stable aggregation was highest (84.5%) for rototilling and lowest (79.3%) for burn-lister tillage. Bulk density increased in all plots, but it increased the least in plots that were moldboard plowed.

72-73:02G-130

SALT TOLERANCE OF MEXICAN WHEAT: I. EFFECT OF NO3 AND NaCl ON MINERAL NUTRITION, GROWTH, AND GRAIN PRODUCTION OF FOUR WHEATS,

Torres, B. C., and Bingham, F. T.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 711-715, September-October, 1973. 5 fig, 8 tab, 15 ref.

Descriptors: *Fertility, *Crop response, *Salinity, Nutrients, Nitrogen, Crop production, Soil chemical properties, Crops.

Wheat plants were grown to full maturity under sand culture conditions with variable levels of substrate NO3 and NaCl. Leaf samples were collected at early spike emergence for chemical analysis of Ca, Mg, Na, K. P. Cl, NO3, and total N. Growth measurements included those of flag leaf length, tiller and spike formation, and total straw and grain. The slower maturing variety, Cajeme 71, grew much more vigorously than the more rapidly maturing varieties Inia 66, Yecora, and Siete Cerros. The salt tolerance of Cajeme 71 was 2- to 4-fold greater than that of the other varieties tested. Leaf NO3 of samples collected at early spike emergence correlated with grain yields irrespective of substrate NaCl levels, suggesting that the growth retardation associated with excessive substrate NaCl was due in part to a Cl-induced NO3 deficiency.

72-73:02G-131
A MATHEMATICAL INVESTIGATION OF STEADY INFILTRATION FROM LINE SOURCES,
Zachmann, D. W., and Thomas, A. W.
Colorado State University, Fort Collins, Department of Mathematics.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 495-500, July-August 1973. 4 fig, 8 ref.

Descriptors: *Infiltration, *Soil water movement, *Subsurface irrigation, Evaporation, Equations, Hydraulic conductivity.

Equations which can be used in the design of subsurface irrigation systems are based on the physics of steady infiltration from a distribution of line sources which lie in a horizontal plane and are parallel and equally spaced. The analytical solution describes the flow from the line sources in the presence of uniform infiltration or evaporation at the soil surface. To increase the utility of the solution, the equations for matric flux potential and stream function are written in dimensionless form.

72-73:02G-132
RECOVERY OF N15-LABELED FERTILIZERS IN FIELD EXPERIMENTS,
Westerman, R. L., Kurtz, L. T., and Hauck, R. D.
Illinois University, Urbana.
Soil Science Society of America Proceedings, Vol. 36, No. 1, p 82-86, January-February, 1972. 2 fig, 3 tab, 14 ref.
(See 72-73:05B-072)

72-73:02G-133
APPLIED AND RESIDUAL NITRATE-NITROGEN EFFECTS ON IRRIGATED GRAIN SORGHUM YIELD,
Onken, A. B., and Sunderman, H. D.
Texas A & M University, Agricultural Research and Extension Center, Lubbock.
Soil Science Society of America Proceedings, Vol. 36, No. 1, p 94-97, January-February, 1972. 4 tab, 14 ref.

Descriptors: *Nutrient removal, *Nitrogen, *Crop response, Crop production, Crops, Leaching, Water pollution sources.

Multirate nitrogen studies were conducted for a 3-year period, on an irrigated clay loam soil at two locations, to determine the influence of applied and residual soil N on the yield of grain sorghum. Soil samples were taken prior to fertilizer application in depth increments of 0-15, 15-30, 30-61, and 61-91 cm and analyzed for nitrate. Applied and residual soil NO3-N were found to influence grain yields. Regression analysis of the data showed highly significant relationships between quantities of soil nitrates measured at upper depths to those measured at lower depths, and grain yield and applied N + residual NO3-N. Best correlations were obtained when residual NO3-N was included in the regression equation. Results indicated that soil samples taken to 15 or 30 cm would be sufficient for evaluation of residual nitrogen effects.

72-73:02G-134
PREDICTING OPTIMUM DEPTH OF PROFILE MODIFICATION BY DEEP PLOWING FOR IMPROVING SALINE-SODIC SOILS,
Rasmussen, W. W., and McNeal, B. L.
United States Department of Agriculture, Agricultural Research Service, Snake River Conservation Research Center, Kimberly, Idaho.
Soil Science Society of America Proceedings, Vol. 37, No. 3, p 432-437, May-June, 1973. 2 fig, 3 tab, 14 ref.

Descriptors: *Saline soils, *Deep tillage, *Hydraulic conductivity, Permeability, Soil management, Infiltration.
Identifiers: Deep plowing.

A previously developed procedure for predicting the effect of mixed-salt solutions on soil hydraulic conductivity (HC) was used to predict the relative hydraulic conductivity (RHC) of separate soil horizons from saline-sodic soils, using a standard low-salt solution following a standard high-salt solution at a fixed exchangeable-sodium level. These values were then used to predict the RHC of mixtures of the same horizons simulating profiles modified to various depths by deep plowing. Weighting RHC values for individual horizons by the depth fraction of each horizon in the soil mixture provided RHC values of proper magnitude, except when large proportions of calcareous subsolum material were incorporated into the mixture. Results were improved by multiplying calculated RHC values for each soil mixture by the initial HC of the mixture. Results were consistent with lysimeter and field plot observations on the same soils, including deep plowing trials.

72-73:02G-135
PRIMING EFFECT OF N-15 LABELED FERTILIZERS ON SOIL NITROGEN IN FIELD EXPERIMENTS,
Westerman, R. L., and Kurtz, L. T.
Arizona University, Department of Soils, Tucson.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 725-727, September-October, 1973. 1 tab, 15 ref.

Descriptors: *Nutrient removal, *Nitrogen, Leaching, Crop response, Water pollution sources, Fertilizers, Stable isotopes, Isotope studies.

Evidence of the "priming effect" on the uptake of soil N by additions of conservative amounts of fertilizer N was examined in data from two recently reported field experiments. In these experiments, urea and oxamide each labeled with N15 were compared on adjacent locations in successive years with 'Sudax SX11' Sorghum-sudan hybrid as the test crop. Additions of N fertilizer increased the uptake of soil N by 17 to 45% in the first experiment and by 8 to 27% in the second experiment. In the residual cutting of the first experiment, increases in uptake of soil N by the crops was speculated to be due to stimulation of microbial activity by N fertilizers which increased mineralization of soil N, thus making more soil N available for use by plants.

72-73:02G-136
CROP RESIDUE, SOIL WATER, AND SOIL FERTILITY RELATED TO SPRING WHEAT PRODUCTION AND QUALITY AFTER FALLOW,
Black, A. L.
United States Department of Agriculture, Sidney, Montana.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 754-758,
September-October, 1973. 1 fig, 5 tab, 19 ref.

Descriptors: *Cultivation, *Fallowing, Organic matter, Mulching, Fertilizers, Nitrogen, Phosphorous, Proteins, Wheat.

Over an 8-year period, wheat straw mulch rates of 0, 1,680, 3,360, and 6,730 kg/ha were established each spring on the fallow year in alternate crop-fallow blocks in three replications on a Dooley sandy loam. Fertilizer subplot treatments applied before seeding spring wheat were as follows: Check, N, P, and N plus P. Both elements were applied at a rate of 34kg/ha; N was applied each crop year, and P was applied initially and every other crop year thereafter. After 14 and 21 months of fallow, average available soil water stored to a depth of 1.5 m increased significantly and was positively correlated with increasing residue levels. Each metric ton of surface residue increased average available soil water supplies 0.5 cm. Mean grain yields were positively correlated with stored soil water at seeding only when both N andP were applied. N-P fertilization increased mean grain yields 410, 580, 690, and 760 kg/ha per year for corresponding residue levels of 0, 1,680, 3,360, and 6,730 kg/ha respectively.

72-73:02G-137
MULCH AND TILLAGE RELATIONSHIPS IN CORN CULTURE,
Van Doren, D. M., Jr., and Triplett, G. B., Jr.
Ohio Agricultural Research and Development Center, Wooster.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 766-769,
September-October, 1973. 4 tab, 10 ref.

Descriptors: *Cultivation, *Mulching, *Organic matter, Corn, Water

Relative effects of soil mulch cover and various tillage practices on corn yield were studied as functions of previous crop and rainfall on a typic fragiudalf soil. Residues were removed from the soil prior to tillage, manipulated according to action of the tillage implements, or replaced on the soil surface after tillage. Eight tillage treatments consisted of all possible combinations of moldboard plowing, disking, and post emergence cultivation. Mulch cover produced three times as great a yield effect as any other single variable. Tillage variables increased yield in order of cultivation > plow > disk, and results are expressed in terms of mulch cover required to produce an equal yield effect. Most tillage and mulch effects were additive. The major reason for mulch and tillage effects on corn yield is assumed to be their influence on soil water content. Possible extrapolation of these results to other soils and climates is discussed.

72-73:02G-138
MICRO-DETERMINATION OF CATION-EXCHANGE CAPACITY BY NEUTRON ACTIVATION ANALYSIS,

Dudas, M. J.
Oregon State University, Agricultural Experiment Station, Corvallis.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 804-805,
September-October, 1973. 1 fig, 2 tab, 4 ref.

Descriptors: *Cation exchange, *Gamma rays, Clays,Kaolinite, Montmorillonite.

Neutron activation analysis was evaluated as a method to determine the cation-exchange capacity (CEC) of clay samples. Cation-exchange capacity values of satisfactory reproducibility and accuracy were obtained on 5- to 50-mg subsamples of a kaolinite and montmorillonite clays previously saturated with Na, Rb, or Cs. Use of Cs as the index ion provided the simplest and most flexible conditions for the activation analysis method.

72-73:02G-139
DETERMINATION OF EQUIVALENT RADII FOR RECTANGULAR DRAINS,
Warrick, A. W.
Arizona University, Department of Soils, Water and Engineering, Tucson.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 809-811,
September-October, 1973. 2 fig, 8 ref.

Descriptors: *Drainage, *Subsurface drainage, Tile drainage, Drainage systems, Drains, Drainage practices, Drainage engineering.

A relationship is developed giving the circular drain size which is equivalent to a rectangular drain. A rectangular drain may result when a highly permeable envelope of rectangular cross-section is used around a buried drainage tube. A plot of re/square root of (ab) is given as a function of a/b with re as the circular drain radius and a and b the semi-width and semi-height of the rectangular drain. The minimum value of re/square root of (ab) is 1.18 and corresponds to a square. The equivalent radius is useful in adapting drainage formulas giving spacings, depth, etc., to rectangular drains.

72-73:02G-140
A MODIFIED ION EXCHANGE TECHNIQUE FOR THE DETERMINATION OF STABILITY CONSTANTS OF METAL-SOIL ORGANIC MATTER COMPLEXES,
Ardakani, M. S., and Stevenson, F. J.
California University, Department of Soils and Plant Nutrition, Berkeley.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 884-890,
November-December, 1972. 7 fig, 6 tab, 19 ref.

Descriptors: Ion exchange, Humic acids, Humus, Chelation.

Calculation methods based on Schubert's ion-exchange equilibrium method were developed for determining stability constants of metal-soil organic matter complexes. The methods, which were free of certain assumptions and errors inherent in the ion-exchange technique as applied previously to soil organic matter, were verified using Mn(II)-citrate and Mn(II)-oxalate systems. Apparent stability constants (log K) of Zn (II)-humic acid complexes ranged from 3.13 to 5.13 at pH 6.5.

72-73:02G-141
EFFECT OF PHOSPHATE SALTS AS SATURATING SOLUTIONS IN CATION-EXCHANGE CAPACITY DETERMINATIONS,

Schalscha, E. B., Pratt, P. F., Kinjo, T., and Amar A. J.
Chile University
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 912-914,
November-December, 1972. 3 tab, 19 ref.

Descriptors: *Cation exchange, *Soil chemistry, Salinity, Phosphates, Soil physics, Saline soils.

Cation-exchange capacities with KCl or NaNO3 in volcanic ash soils varied from 6 to 18 meq/100 g whereas CEC with KH2PO4 varied from 78 to 188. Cation-exchange capacities with NaH2PO4 and NaNO3 were 28 and 6, respectively, for an alfisol and 12 and 2, respectively, for an oxisol. The ratios of CEC with H2PO4(-) as compared to Cl(-) or NO3(-) varied from about 4 to 30. The effect of the H2PO4(-) is explained as a result of neutralization of positive charge in the soil with a simultaneous release of negative charge.

72-73:02G-142
RATES OF GROWTH AND NUTRIENT UPTAKE OF IRRIGATED CORN AS AFFECTED BY N AND P FERTILIZATION,
Bar-Yosef, B., and Kafkafi, U.
The Volcani Center, Division of Soil Chemistry and Plant Nutrition, Bet Dagan, Israel.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 931-936,
November-December, 1972. 1 fig, 7 tab, 23 ref.

Descriptors: *Nutrient removal, *Nutrient requirements, *Corn, Phosphorus, Nitrogen, Fertilizers, Soil chemistry.

Growth rates of corn and weekly uptake of major nutrients were measured in a permanent plot fertilization experiment. Bicarbonate-soluble P and NO3-N concentration in the soil were measured four times during the growing period. High levels of nitrates in the soil during the first month of growth suppressed dry matter production. An increase in soil phosphate concentration resulted in higher phosphate uptake and early appearance of male flowers. On the control plots, which had not received any phosphatic fertilizer for 8 years, the plants took up more phosphate than the amount estimated by the bicarbonate method. The high levels of nitrates found in the soil 4 weeks after seeding dropped within the fifth week to a level of 20-10 ppm N. Denitrification to gaseous compounds in the presence of living plants due to 68 mm of sprinkler-applied water is proposed as an explanation of this phenomenon.

72-73:02G-143
DETERMINATION OF TOTAL PHOSPHOROUS IN SOILS: A RAPID PERCHLORIC ACID DIGESTION PROCEDURE,
Sommers, L. E., and Nelson, D. W.
Purdue University, Agricultural Experiment Station, Lafayette, Indiana.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 902-904,
November-December, 1972. 4 tab, 17 ref.

Descriptors: *Fertility, *Phosphorous, Phosphates, Nutrients, Soil chemical properties, Soil properties, Topsoil.

Extraction and colorimetric methods were evaluated for determining total P in soils. A procedure involving simultaneous digestion of 60 soil samples with perchloric acid and determination of extracted orthophosphate with an ascorbic acid method was evaluated. Analysis of diverse soils indicated that the proposed and conventional HC104 digestion procedures yielded essentially the same total P values; however, both HC104 methods underestimated total P by 1-6% when compared to Na2CO3 fusion. A comparison of colorimetric orthophosphate procedures indicated the method of Murphy and Riley (1962) was suitable for determination of orthophosphate following either HC104 digestion of Na2CO3 fusion. Determination of total P in soils by tube HC104 digestion and estimation of extracted P by the method of Murphy and Riley (1962) enables rapid and precise estimation of total P in a wide range of soils.

72-73:02G-144

GROWTH, MINERAL COMPOSITION, AND SEED OIL OF SESAME AS AFFECTED BY BORON AND EXCHANGEABLE SODIUM,

Yousif, Y. H., Bingham, F. T., and Yermanos, D. M.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 923-926, November-December, 1972. 2 fig, 3 tab, 17 ref.

Descriptors: *Salinity, *Alkali soils, Sodium, Boron, Chemical properties, Soil chemistry, Saline soils, Salts.

A solution culture boron experiment was conducted with sesame to show the effects of excessive B. The boron content of leaf blades, petioles, and stems was highly correlated with substrate boron. The leaf blades contained the highest amount of boron, and the stems the least. Concentrations of 5 mg B/liter or higher inhibited growth, seed production, and resulted in a leaf necrosis and premature leaf drop. Foliage of plants receiving excess B contained less micrograms B/g on a dry weight basis. An exchangeable sodium experiment using clay soil with and without a synthetic soil conditioner showed that yields were sharply reduced at an ESP level of 15 or greater. Leaf blade sodium was higher for the treatments without the soil conditioner but in both series, 50% growth depression was associated with leaf values of about 0.4% Na. Potassium and Mg in the leaf blades did not vary significantly, and although calcium was decreased 50% with increasing ESP, no visual deficiency symptoms were detected.

72-73:02G-145

CALCIUM, MAGNESIUM, AND POTASSIUM SATURATION RATIOS IN TWO SOILS AND THEIR EFFECTS UPON YIELDS AND NUTRIENT CONTENTS OF GERMAN MILLET AND ALFALFA,

McLean, E. O., and Carbonell, M. D.
Ohio State University.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 927-930, November-December, 1972. 3 tab, 16 ref.

Descriptors: *Salinity, Saline soils, Nutrients, Calcium, Magnesium, Potassium, Alfalfa, Crop response.

A greenhouse study involving sequential cropping of two soils of differing cation exchange capacities with five Ca-Mg saturation ratios at two K levels was conducted. German millet followed by alfalfa was grown with Mg-Ca saturations varied from Mg 5%-Ca 75% to Mg 25%-Ca 55% at two K levels. German millet yields were not affected in the above range of Ca-Mg saturations. However, an apparent Mg response occurred when alfalfa yields were more than doubled by increasing initial Mg and Ca saturations from 3 and 18% to 5 and

75%, respectively. Exchangeable Mg and Ca contents in the soils after cropping plus amounts removed by cropping were less than the initial contents in one soil and were more than the initial contents in the other. Evidently some type of fixation mechanism tied up Mg and Ca in the former while solubilization of residual lime released them in the latter.

72-73:02G-146
VERTICAL MULCH EFFECTS ON SOIL WATER STOPAGE,
Fairbourn, M. L., and Gardner, H. R.
Agricultural Research Service, Fort Collins, Colorado, Soil and Water Conservation Research Division.
Soil Science Society American Proceedings, Vol. 36, No. 5, p 823-827, 1972.
Illus.

Identifiers: Diffusivity, Evaporation, *Mulch, *Soil-water storage, Watersheds, Infiltration, *Soil treatments.

Soil water storage for vertical mulch and furrow treatments on level soil surfaces and vertical mulch and nonmulch treatments with microwatersheds was evaluated in a constant temperature laboratory. The vertical mulch treatment on a level surface saved 30-40% more of the applied water than the furrow treatment. The efficiency of storage with vertical mulch was reduced by 17% when the surrounding soil surface was wet during water application. A microwatershed with vertical mulch stored 7-10% more of the applied water than a microwatershed without mulch. Depth of water infiltration and dry soil surface adjacent to the mulch appeared to be the factors that reduced evaporation losses from vertical mulch treatments. A comparison of scaled evaporation data with the diffusivity curve for the soil used demonstrated that the diffusivity equation was useful for predicting soil water loss by evaporation for microwatershed treatments of this experiment.

72-73:02G-147
INTERACTING DIFFUSE LAYERS IN MIXED MONO-DIVALENT IONIC SYSTEMS,
Bresler, E.
The Volcani Center, Agricultural Research Organization, Bet Dagan, Israel.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 891-896, November, 1972. 7 fig, 1 tab, 19 ref.

Descriptors: *Cation exchange, *Cations, Analog computers, Computer models, Ion exchange.

A numerical solution of the electric double-layer problem for the case of overlapping diffuse layers in mixed monovalent-divalent ion systems, is used to obtain a series of graphs for various cation compositions in the external solution. In these graphs, the electric potential is expressed as a function of the surface charge density, the concentration of the two cations in the equilibrium solution, and the distance between platelets in various ionic mixtures. The graphs cover most of the situations usually encountered in soil systems, and are not sensitive to the valency of the anions present. They are used to estimate pressures, and electrokinetic phenomena in mixed-ion clay systems. Application of these estimates to theoretical models and experimental data are illustrated. Some of the examples used for this illustration are based on work previously published by others.

72-73:02G-148
SPECTROPHOTOMETRIC DETERMINATION OF SOIL WATER CONTENT,
Bowers, S. A., and Smith, S. J.
United States Agricultural Water Quality Management Laboratory, Durant, Oklahoma.
Soil Science Society of America Proceedings, Vol. 36, No. 6, p 978-980, November-December, 1972. 2 fig, 1 tab, 9 ref.

Descriptors: *Soil moisture, *Soil moisture meters, Spectrophotometry, Measurement.

The absorbance at 1.94 microns by a soil-methanol extract was used for measuring the soil water contents of three different textured soils. A linear relation between absorbance and soil water content was adequate for moisture determinations ranging from air dry to the moisture equivalent. For Quincy loamy sand and Barnes loam soils, calibration based only on laboratory standards was sufficient. For Houston Black clay, calibration against oven-dry samples was necessary.

72-73:02G-149
WATER TRANSMISSION PROPERTIES OF AN ASPHALT BARRIER,
Palta, J. P., Blake, G. R., and Farrell, D. A.
Minnesota University, St. Paul, Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 36, No. 5, p 709-714, 1972. Illus.

Identifiers: *Asphalt barrier, Capillary potential, Discontinuities, Flow, Soils, *Water transmission, *Steady flow soil columns.

The water transmission properties of an asphalt barrier were studied using samples taken from a barrier formed in Zimmerman fine sand. Steady flow experiments using a 9.0-cm diameter soil column showed that water movement through the barrier was affected by the capillary potentials on both sides of the barrier if these potentials exceeded a critical value or 'break point' which ranged from minus 32 to minus 20 cm depending on the flow rate. This steady value increased from minus 4.3 to minus 1.5 cm when the flow rate was increased from 0.009-0.058 cm/hr. The hysteretic flow properties of the barrier are explained using a model based on the following assumptions: flow occurs mainly through cracks of varying width, and the ratio of the draining to wetting potentials of the cracks exceeds unity and is independent of crack size.

72-73:02G-150
SATURATED-UNSATURATED SEEPAGE BY FINITE ELEMENTS,
Neuman, S. P.
The Volcani Center, Agricultural Research Organization, Bet Dagan, Israel.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY12, p 2233-2250, December, 1973. 9 fig, 19 ref.

Descriptors: *Porous media, *Flow, *Hydraulics, Saturated soils, Unsaturated flow, Seepage, Computer models, Mathematical models, Finite element analysis.

A Galerkin-type finite element method is employed to solve the quasilinear partial differential equations of transient seepage in saturated-unsaturated porous media. The resulting computer program is capable of handling nonuniform flow regions having complex boundaries and arbitrary degrees of local anisotropy. Flow can take place in a vertical plane, in a horizontal plane, or in a three-dimensional system with radial symmetry. An arbitrary number of seepage faces can be considered simultaneously, and the positions of the exit points on these boundaries are adjusted automatically during each time step. Two examples, one of seepage through an earth dam with a sloping core and horizontal drainage blanket, and the other of seepage through a layered medium cut by a complex topography, are included. These examples indicate that the classical concept of a free surface is not always applicable when dealing with transient seepage through soils.

72-73:02G-151
INFILTRATION AND ANTECEDENT PRECIPITATION,
Papadakis, C. N., and Preul, H. C.
Michigan University, Ann Arbor, Department of Civil Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY8, Paper 9940, p 1235-1245, August 1973. 4 fig, 1 tab, 11 ref, append.

Descriptors: *Infiltration, *Antecedent precipitation, *Hortons law, Infiltration rates, Soil water movement, Infiltrometers.

A simple, inexpensive, and expedient method is presented for determining the initial infiltration capacity (fo), the decay rate of infiltration (k), and the constant infiltration capacity (fc) to be used in Horton's equation. The method consists of performing a series of infiltration tests using flooding-type test tube infiltrometers for different antecedent precipitation conditions. Horton's equation is fitted to the available data, thus obtaining values of fo, fc and k for each test. Daily rainfall records are used, starting at least 2 months prior to the infiltration tests, to determine the antecedent precipitation index values corresponding to each test. Curves of antecedent precipitation index plotted against Horton's constants provide the designer with the proper values of fo and K for the soil on which infiltration tests were performed for any specified antecedent condition.

72-73:02G-152
RAINFALL EXCESS MODEL FROM SOIL WATER FLOW THEORY,
Smith, R. E., and Chery, D. L., Jr.
Agricultural Research Service, Tucson, Arizona, Southwest Watershed Research Center.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY9, Paper 9990, p 1337-1351, September 1973. 13 fig, 9 ref, append.

Descriptors: *Rainfall-runoff relationships, *Infiltration, Mathematical models, Computer programs, Hydraulics, Overland flow, *Soil water movement, Rainfall intensity, Antecedent precipitation, Precipitation excess, Model studies.

The complex (computer-dependent) solution of the partial differential equation for unsaturated soil moisture flow equation was used to develop a simple parametric description of the performance of a variety of soils under various rainfall input rates and patterns, and initial moisture contents. This description is expressed in terms of an infiltration model that is dependent on accumulated soil water. The model is incorporated in a kinematic model of rainfall-runoff response, and its predictions are compared with those of an empirical model of infiltration developed by the USDA Hydrograph Laboratory. The results emphasize the practical utility of the model and its potential advantages over comparable empirical models as well as the inadequate sensitivity of equipment currently used to measure rainfall and runoff from small plots.

72-73:02G-153
RELATION BETWEEN EVAPOTRANSPIRATION RATE AND MAIZE YIELD,
Hillel, D., and Guron, Y.
Hebrew University of Jerusalem, Department of Agriculture, Rehovot, Israel.
Water Resources Research, Vol. 9, No. 3, p 743-748, June, 1973. 2 fig, 1 tab, 19 ref.

Descriptors: *Irrigation practices, *Crop response, *Evapotranspiration, Consumptive use, Water requirements, Corn, Efficiencies.

Water use efficiency is evaluated in terms of the ratio of dry matter yield to seasonal evapotranspiration. A 5-year maize irrigation experiment was conducted in which the root zone soil moisture balance and crop response were measured in relation to potential and actual evapotranspiration. A threshold evapotranspiration of 250-300 mm was indicated below which production was negligible and above which production rose linearly with the amount of water applied. Water use efficiency increased with higher quantities of irrigation provided that soil aeration was not impeded and potential evapotranspiration was not exceeded. It is concluded that a 'wet' irrigation regime, permitting the drop to transpire at a rate approaching the climatically induced potential and simultaneously preventing the occurrence of moisture deficits, can help to realize the full productivity of the crop.

72-73:02G-154
UNSATURATED FLOW PROPERTIES USED TO PREDICT OUTFLOW AND EVAPOTRANSPIRATION FROM A SLOPING LYSIMETER,
Scholl, D. G., and Hibbert, A. R.
United States Department of Agriculture, Forest Hydrology Laboratory, Tempe, Arizona.
Water Resources Research, Vol. 9, No. 6, p 1645-1655, December, 1973. 12 fig, 6 ref.

Descriptors: *Lysimeters, *Runoff, *Drainage, Evapotranspiration, Grasses, Forest soils, Forest watersheds, Forestry.

Field measurements of soil moisture content and pressure potential were used to determine the moisture flux, hydraulic gradients, and dynamic conductivity of a 200-foot sloping soil lysimeter. These measurements were then used to predict outflow and evapotranspiration. A vertical unsaturated Darcian analysis was used to evaluate conductivity during the first study phase, in which evapotranspiration was eliminated by sealing the model surface with a plastic sheet. The moisture flux term in the Darcy equation was determined by evaluating moisture content change in depth and time. Moisture flux determined in this was agreed with measurements of actual outflow. Conductivities were solved from flux and hydraulic gradients, and corresponding water contents were assigned. Conductivity curves were highly significant and agreed with those obtained when the model was uncovered. Evapotranspiration was solved during the second study phase (cover removed and grass established) by using a water balance based on moisture content and potential, rainfall, and conductivity (from the first study phase). Results at the deepest levels in the profile agreed well with those based on actual outflow.

72-73:02G-155
WATER TABLE MOVEMENT DURING SUBIRRIGATION,
Skaggs, R. W.
North Carolina State University, Biological and Agricultural Engineering Department, Raleigh.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 5, p 988-993, September- October, 1973. 10 fig, 18 ref.

Descriptors: *Irrigation practices, *Subirrigation, *Water table, Mathematical models, Computer models, Drainage, Irrigation systems, Irrigation design.

The movement of the water table for subirrigation conditions was characterized by numerically solving a nonlinear differential equation describing unsteady flow above a horizontal impermeable layer. Solutions were presented for both initially draining and horizontal water table profiles. Approximate solutions were derived and compared to the numerical results. The effect of water loss by evapotranspiration and deep seepage on the water table rise during subirrigation was also determined by numerical methods. It was concluded that an approximate solution can be used to reliably predict the movement of the water table midway between drains.

72-73:02G-156
CONTROLLING AUTOMATED IRRIGATION WITH SOIL MATRIC POTENTIAL SENSOR,
Phene, C. J., Hoffman, G. J., and Austin, R. S.
United States Department of Agriculture, Coastal Plains Soil and Water Conservation Research Center, Florence, South Carolina.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 4, p 773-776, July-August, 1973. 7 fig, 7 ref.

Descriptors: *Irrigation, *Automatic control, Soil moisture, Moisture meters, Moisture tension, Moisture availability, Crop response, Moisture content, Soil water.

The successful use of a soil matric potential sensor to control automatic irrigation has been demonstrated in both the laboratory and the field. The soil matric potential in a soil-plant system was controlled automatically at -0.15 ±0.01 bar in the laboratory when the system was subjected to variable temperatures. Irrigations were also controlled automatically at -7.6 ±0.5 bars in a soil-plant system. In the field, the soil matric potential at the 15-cm depth was automatically controlled at -0.21 ±0.05 bar and -0.27 ±0.03 bar in plots planted to sweet corn. The fluctuation of the soil matric potential measured could have been further reduced by increasing the duration of water application at each irrigation. This in no way reflects on the capability of the sensor to control the irrigation system. The sensor called for irrigation when water was needed.

72-73:02G-157
REMOTE SENSING OF FALLOW SOIL MOISTURE BY PHOTOGRAPHY AND INFRARED LINE SCANNER,
Allen, W. H., and Sewell, J. I.
Mississippi State University, Agricultural and Biological Engineering Department, Starkville.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 4, p 700-706, July-August, 1973. 5 fig, 3 tab, 14 ref.

Descriptors: *Remote sensing, *Soil moisture, Fallowing, Infrared radiation, Environmental engineering, Soil water, Soil science, Soil physics.

A laboratory investigation of the relationship between reflectance of bare soil and soil moisture level at wavelengths throughout the visible and into the near infrared was implemented. A definite relationship was found between soil moisture and reflectance. This was adequately described by a quadratic function. Remote sensing appears to be potentially valuable in environmental analysis associated with soil moisture conditions. A definite need remains for further definition and evaluation of the basic relationship as well as the inclusion of more related variables.

72-73:02G-158
EXPERIMENTAL EVALUATION OF A METHOD FOR DETERMINING UNSATURATED HYDRAULIC CONDUCTIVITY,
Skaggs, R. W., Monke, E. J., and Huggins, L. F.
North Carolina State University, Biological and Agricultural Engineering Department, Raleigh.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 1, p 85-88, January-February, 1973. 9 fig, 17 ref.

Descriptors: *Soil moisture, *Soil water, Soil water movement, Unsaturated flow, Hydraulic conductivity, Hydraulics, Groundwater movement.

An experimental investigation was conducted to evaluate an approximate method of determining the hydraulic conductivity function of unsaturated soil. The method was based on the assumption that the conductivity-pressure head relationship could be effectively represented by an empirical 3-parameter equation presented by Gardner (1958). The conductivity functions of two artificially packed soils were determined. Infiltration rate-time relationships were then measured for infiltration into soil columns having different initial water content distributions. These relationships were compared to influx curves predicted through the use of the determined K(h) functions.

72-73:02G-159
FIELD EVALUATION OF TRANSIENT DRAIN SPACING EQUATIONS,
Skaggs, R. W., Kriz, G. J., and Bernal, R.
North Carolina State University, Biological and Agricultural Engineering Department, Raleigh.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 3, p 590-595, May-June, 1973. 6 fig, 3 tab, 16 ref.

Descriptors: *Drainage, *Groundwater movement, Drainage practices, Subsurface drainage, Tile drainage, Soil water movement, Crop response, Irrigation effects.

Field experiments were conducted on a subirrigation-drainage system to determine the applicability of four drain spacing equations for a shallow sandy loam soil. The water table drawdowns following subirrigation and rainfall events were measured for drain spacings of 7.5, 15 and 30 m. Drain spacings were calculated using four theoretical equations and were compared to the actual spacings. The results of the experiments show that for soils with shallow water tables, the application of rainfall will result in a sharp rise in the water table elevation. The total rise and response time of the water table will depend on its initial depth, the rate and amount of rainfall, andthe soil hydraulic properties.

72-73:02G-160

SHALLOW DRAIN PERFORMANCE IN HEAVY SOIL,

Hermsmeier,L. F.
United States Department of Agriculture, Imperial Valley Conservation Research Center, Brawley, California.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 1, p 92-94, 96, January-February, 1973. 3 fig, 5 tab.

Descriptors: *Drainage, *Subsurface drainage, Tile drainage, Drainage systems, Drainage engineering, Drainage area, Drainage programs.

Shallow drains installed at a 4-foot depth and 200-foot spacing in a clay and loamy clay soil removed only from 12 percent to 7.2 percent of the salt added by the irrigation water during four cropping seasons over a 2-1/2 year period. The small amount of salt removed by the drains, when combined with salt removed from the soil by the natural drainage, was sufficient to maintain a favorable salt balance. However, during the sugarbeet cropping season when only 7.2 percent of the salt added by the irrigation water was removed by the drains there was an unfavorable salt balance in the field. Shallow drains can provide the means for removing sufficient salt from the soil to maintain a favorable salt balance when combined with natural drainage and good irrigation practice.

72-73:02G-161

DEVELOPMENT OF AN AGRICULTURAL DRAINAGE GUIDE,

Dickey, G. L., and Johnston, W. R.
United States Department of Agriculture, Soil Conservation Service, Berkeley, California.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 1, p 97-99, January-February, 1973. 6 fig, 6 ref.

Descriptors: *Drainage, *Subsurface drainage, Tile drainage, Drainage systems, Drainage engineering, Drainage area, Drainage programs.
Identifiers: Drainage guide.

A simplified procedure for field investigation and design of subsurface drainage systems was developed for western Fresno County, California. Data was collected to a depth of 20 feet or more in deep soil in order to analyze the drainage problem. Standard soil surveys to the depth of 5 feet are of little value in determining drain depth requirements in deep soils; however, a correlation was found between 0 to 5-foot soil characteristics and the drainage coefficient. Existing drainage systems are needed for study and evaluation. This allows a drainage guide to be developed on actual drain performance.

72-73:02G-162

SOIL CRUSTING RELATED TO SPRINKLER INTENSITY,

Busch, C. D., Rochester, E. W., and Jernigan, C. L.
Auburn University, Agricultural Experiment Station, Auburn, Alabama.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 4, p 808-809, July-August, 1973. 5 fig, 2 tab, 10 ref.

Descriptors: *Irrigation practices, *Sprinkler irrigation, Soil physics, Soil cement, Soil management, Soil properties, Soil stability, Soil surfaces, Soil texture.
Identifiers: Soil crusting.

It was found that crust strengths developed under two different sprinkling intensities persist over three wetting and drying cycles. Lower sprinkler application rates consistently produced a weaker crust. Increasing the number of water application cycles did not show a consistent effect on crust strength. Previous sprinkling may reduce the strength of a crust formed by a subsequent rainfall.

72-73:02G-163
GRAIN SORGHUM RESPONSE TO TRICKLE AND SUBSURFACE IRRIGATION,
Hiler, E. A., and Howell, T. A.
Texas A & M University, Agricultural Engineering Department, College Station.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 4, p 799-803, July-August, 1973. 5 fig, 3 tab, 18 ref.

Descriptors: *Irrigation, *Surface irrigation, *Subsurface irrigation, Distribution systems, Irrigation systems, Mist irrigation, Lysimeter, Water utilization, Crop response.

Grain sorghum was grown during 1971 and 1972 in a field lysimeter installation in which control of the soil water could be maintained. Undisturbed soil cores approximately one meter in diameter and two meters deep made up the lysimeters. Rainfall was kept off the lysimeters with an automated shelter system. Irrigation treatments during 1971 included Subsurface, Trickle, Subsurface plus Mist, Trickle plus Mist, Mist, and Surface. All treatments involving subsurface and trickle irrigation were irrigated every third day in an amount calculated to bring the soil water content to "field capacity". The Mist treatment was "overmisted" slightly so that the soil water potential would be maintained between 0 and -0.7 bar. The Surface treatment was irrigated when the soil water potential in the root zone reached -0.7 bar in the amount of 1.1 times measured depletion.

72-73:02G-164
AN ECONOMICAL HYDRAULIC WEIGHING EVAPOTRANSPIRATION TANK,
Dylla, A. S., and Cox, L. M.
United States Department of Agriculture, Agricultural Research Service, Morris, Minnesota.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 2, p 294-295, 301, March-April, 1973. 5 fig, 2 ref.

Descriptors: *Lysimeters, *Weight, Evapotranspiration, Instrumentation, Moisture meters, Moisture content, Soil water, Water loss.

Experimental tests were conducted in 1965-1966 in Nevada on large soil-filled tanks, 152.5 cm in diameter by 198 cm. deep, supported on 30.5-m lengths of 5-cm diameter butyl irrigation tubing filled with a water-methanol mixture. The tubing was coiled to provide about 90 percent bottom area support. The sensitivity of the weighing system of the low-cost butyl tubing-supported ET tanks is adequate for many evapotranspiration periods. Fabricating the tanks of plain 2.79-mm thick rolled steel with no special reinforcing or structural supporting members minimizes costs. The water-filled butyl irrigation tubing provides a flexible supporting pad that tends to resist imbalanced loads. Routing all hydraulic pressure lines below ground level to a temperature-controlled manometer pit minimizes thermal error and the need for temperature corrections. The cylindrical tank also adapts readily to taking undisturbed and vegetated soil monoliths.

72-73:02G-165
WATER INTAKE RATES ON A SILT LOAM SOIL WITH VARIOUS MANURE APPLICATIONS,
Cross, O. E., and Fischbach, P. E.
Nebraska University, Agricultural Engineering Department, Lincoln.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 2, p 282-284, March-April, 1973. 9 fig, 5 ref.

Descriptors: *Irrigation practices, *Permeability, Soil physics, Soil structure, Soil amendments, Soil density, Soil management, Soil texture, Organic matter.

Feedlot manure was applied to and incorporated into a sharpsburg silt loam soil. Four levels of manure were applied and the plots disk plowed to three depths. During 1970 the crops were irrigated three times and during 1971, four times. Water infiltration rates were determined from data of the inflow-outflow method. The initial water intake rate increased as the quantity of manure application increased. The basic water intake rate increased as more time from date of manure application had elapsed. Manure application decreased the basic intake rate as compared to the basic intake rate of non-manured silt loam soil. Depth of plowing did not appreciably affect the basic intake rate.

72-73:02G-166
SUBSURFACE DRAINAGE AND IRRIGATION FOR SUGARCANE,
Carter, C. E., and Floyd, J. M.
United States Department of Agriculture, Agricultural Research Service, Baton Rouge, Louisiana.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 2, p 279-281, 284, March-April, 1973. 6 fig, 7 ref.

Descriptors: *Irrigation practices, *Subsurface irrigation, *Drainage, Subsurface drainage, Tile drainage, Soil water movement, Crop response, Sugarcane.

Water management practices, particularly subsurface drainage, increased annual sugarcane yields from 24 to 62 percent over those from check plots and increased the number of crops grown after a single planting from the normal three to five. No response to irrigation was recorded. Sucrose content of the cane's juice decreased as cane yields increased. Extra cane produced by the treated plots more than compensated for the lower percent sucrose; consequently, sugar yields per acre were higher from the treated plots.

72-73:02G-167
ON THE SOLUTION OF TRANSIENT FREE-SURFACE FLOW PROBLEMS IN POROUS MEDIA BY THE FINITE ELEMENT METHOD,
Cheng, R. T., and Li, C. Y.
State University of New York, Department of Engineering and Applied Sciences, Buffalo.
Journal of Hydrology, Vol. 20, No. 1, p 49-63, September, 1973. 9 fig, 15 ref.

Descriptors: *Porous media, *Soil physics, *Flow, Free surfaces, Computer models, Mathematical models, Drainage.

A numerical procedure is presented to deal with solution of transient free-surface flows in porous media. The governing boundary-value problem for the piezometric potential is solved by the finite element method. The initial-value problem which describes the transient motion of the free-surface is solved by the method of quasi-linearization. The numerical scheme has been applied to isotropic and anisotropic earth dam problem and also to a ditch drainage problem. Excellent agreements have been reached when compared with known solutions. This computational procedure is shown to be stable and suitable for this class of problems with the aid of a digital computer.

72-73:02G-168
NUMERICAL STUDIES OF TWO-DIMENSIONAL SATURATED/UNSATURATED DRAINAGE MODELS,
Todsen, M.
Oslo University, Institute of Geophysics, Oslo, Norway.
Journal of Hydrology, Vol. 20, No. 4, p 311-326, December, 1973. 10 fig, 15 ref.

Descriptors: *Drainage, *Computer models, Saturated flow, Unsaturated flow, Groundwater movement, Soil water, Drainage design.

The partial differential equation which governs the seepage of water in unsaturated and saturated porous media is solved numerically by a generalized Newton iteration technique for two models, one ditch drainage model and one earth dam model. For each model, which is two-dimensional, a few hypothetical soils with different moisture retention curves are considered. In both models only drainage from an initially saturated soil occurs; thus, the problem of hysteresis is avoided. The results of the computations are compared with those of corresponding saturated models; solutions obtained earlier by this author and others. Computational instability phenomena appear when the slope of the retention curves is made steep, i.e., for poorly-graded soils.

72-73:02G-169
WATER WITHDRAWAL BY PLANT ROOTS,
Feddes, R. A., and Rijtema, P. E.
Institute for Land and Water Management Research, Wageningen, The Netherlands.
Journal of Hydrology, Vol. 17, No. 1/2, p 33-59, October, 1972. 10 fig, 5 tab, 24 ref.

Descriptors: *Soil moisture, *Root systems, *Soil-water-plant relationships, Absorption, Water utilization, Plant growth, Moisture availability.

An analysis of the transport resistance for liquid flow in the plant as well as an investigation on the geometry factor of the root system for red cabbage is presented. The variation of these factors with depth is described, and root extraction rates at different depths are calculated and compared with data obtained from water balance studies. The plant resistance data are in reasonable agreement with existing literature. Because of a non-homogeneous and poor root development in the early stages of growth, the geometry data of the initial growing stages differ a factor ten from data found in literature. With root development increasing with depth, geometry data decrease to values also reported for other crops.

72-73:02G-170
SOIL MOISTURE PROFILE UNDER STEADY INFILTRATION,
Lin, S. S., Rochester, E. W., and Hermanson, R. E.
Auburn University, Department of Agricultural Engineering, Auburn, Alabama.
Journal of Agricultural Engineering Research, Vol. 18, No. 3, p 179-187, September 1973. 8 fig, 2 tab, 4 ref.

Descriptors: *Soil moisture, *Soil water, *Infiltration, Groundwater movement, Infiltration rates, Permeability, Porosity, Runoff.

Finite difference procedures were applied in the solution of time and space dependent differential equations describing moisture potential and content. The problem under consideration was a homogeneous soil profile with a constant water table at 120 cm. Initially the soil moisture was at static equilibrium. Constant infiltration was initiated and continued until dynamic equilibrium was approximated. The resulting moisture content and pressure profiles are presented graphically for a number of time intervals and relative infiltration values. Zones of constant moisture content and pressure are discussed.

72-73:02G-171
DELAYS IN THE OPERATION OF SUBSURFACE DRAINAGE TRENCHING MACHINES,
Fisk, S. D., Broughton, R. S., and Norris, E. R.
Quebec Ministry of Agriculture and Colonization, Buckingham, Quebec, Canada.
Canadian Agricultural Engineering, Vol. 14, No. 2, p 69-71, December, 1972.
1 fig, 2 tab, 3 ref.

Descriptors: *Drainage, *Trenches, *Construction, Subsurface drainage, Tile drainage, Installation, Drainage systems, Drainage engineering.

Observations of four, wheel-type, subsurface drainage trenching machines showed that delays accounted for 53.3-65.9 percent of total working-day time. The delays that appear to be most easily reduced include setting targets (5.7 percent time loss), making junctions (3.8 percent time loss), and moving to new job sites (3.7 percent time loss). Based on 174 available working days, the average effective digging time was an equivalent of only 72 days. By decreasing these time losses, the operational efficiency of subdrainage trenching can be improved and considerable savings can be made.

72-73:02G-172
PLANT AND IRRIGATION WATER REQUIREMENTS,
Frost, K. R.
Irrigation Journal, Vol. 23, No. 6, p 10, November-December, 1973.

Descriptors: *Soil-water-plant relationships, Crop response, Evapotranspiration, Soil moisture, Soil water, Soil chemistry.

A brief, descriptive outline of the factors affecting crop water use is presented. A description of the irrigation scheduling processes is given in simple terms.

72-73:02G-173
A LONG-TIME WATER-TABLE STUDY OF AN IRRIGATION PROJECT IN SOUTHERN ALBERTA,
Rapp, E., and van Schaik, J. C.
Canada Agriculture, Research Station, Lethbridge, Alberta.
Canadian Agricultural Engineering, Vol. 14, No. 1, p 29-32, June, 1972. 3 fig, 2 tab, 5 ref.

Descriptors: *Drainage, *Groundwater, *Water table, Drainage, Drainage engineering, Irrigation, Groundwater movement, Soil water.

Water-table levels were measured for a period of 15 years in the Vauxhall District. The seasonal mean water-table depth was 169 cm with a standard deviation of ±10 cm. On the average, 64% of the area had a water table higher than the accepted standard of 183 cm. Although variability in some Units was high, mean seasonal water-table data indicate that no serious drainage problem exists in the Vauxhall District. There was no consistent relationship between irrigation water used or the total hydrologic input and the concurrent water-table depth. This indicates that the water table in the Vauxhall District is not a direct function of either irrigation or seasonal rainfall on a long-term basis.

72-73:02G-174
MAXIMUM CORN YIELDS WITH MINIMUM WATER,
Irrigation Age, Vol. 7, No. 10. p 18-20, 22-23, May, 1973. 1 fig, 4 tab.

Descriptors: *Irrigation practices, *Surface irrigation, Soil moisture, Soil water, Crop response, Corn.

The development of automated irrigation has introduced the possibility of a new concept to irrigation water management. That is, not completely refilling the root zone each irrigation; thereby leaving soil moisture storage capacity within the root zone to take advantage of any rainfall that occurs during the irrigation season. The old recommendation of refilling the root zone each irrigation is wasteful in both fertilizer and water. It is wasteful in that if rainfall occurred soon after the field was irrigated, water would percolate below the root zone carrying soluble nutrients with it, such as nitrates.

72-73:02G-175
A SIMPLE METHOD OF DRIP IRRIGATION,
DeRemer, E. D.
Agronomics, Incorporated, Avondale, Arizona.
Irrigation Journal, Vol. 22, No. 3, p 10-15, May-June, 1972. 8 fig, 5 ref.

Descriptors: *Irrigation practices, Surface irrigation, Application equipment, Soil moisture, Tensiometers, Evaporation, Crop responses.
Identifiers: Drip irrigation, Irrigation timing.

A simple method for determining when and how much to irrigate using a drip system has been developed. The only climatological data required is pan evaporation. The calculations are simple and can be carried out by non-technical persons. Tensiometers are used to determine when irrigation is needed.

72-73:02G-176
CONTROLLING SOIL CRUSTING WITH PHOSPHORIC ACID TO ENHANCE SEEDLING EMERGENCE,
Robbins, C. W., Carter, D. L., and Leggett, G. E.
United States Department of Agriculture, Agricultural Research Service, Snake River Conservation Research Center, Kimberly, Idaho.
Agronomy Journal, Vol. 64, No. 2, p 180-183, March-April, 1972. 3 tab, 15 ref.

Descriptors: *Soil physics, *Soil aggregates, Soil management, Sugar beets, Fertility, Phosphorus, Soil structure, Soil treatment.
Identifiers: Soil crusting, Phosphoric acid.

A study was conducted to determine if spraying dilute phosphoric acid in narrow bands along the seeded rows would increase sugar beet seedling emergence by preventing or minimizing soil crusting and provide the needed nutritional P for crop production. Dilute phosphoric acid was sprayed along rows seeded to sugar beets on a Portneuf silt loam. Several acid concentrations and P rates were applied. Stand counts were made before and after thinning, and P concentrations were measured in sugar beet petioles sampled at three dates during the growing season. Laboratory studies were conducted to determine the effects of the phosphoric acid on soil properties. Applying 69 kg P/ha as dilute phosphoric acid in liquid volumes of 650 to 1,300 liters/ha reduced crusting by increasing aggregate stability in the soil surface, increased sugar beet seedling emergence, and provided the P needed by the sugar beet crop.

72-73:02G-177
COMBINING EXPERIMENTS TO PREDICT FUTURE YIELD DATA,
Cady, F. B., and Allen, D. M.
Cornell University, Ithaca, New York.
Agronomy Journal, Vol. 64, No. 2, p 211-214, March-April, 1972. 3 fig, 2 tab, 6 ref.

Descriptors: *Regression analysis, *Yield equations, Soil tests, Fertility, Fertilization.

Data from a series of fertility experiments including uncontrolled environmental variables are analyzed so that future yields may be predicted. A new criterion, the prediction sum of squares, based on the performance of the estimated equation for predicting observations not included in the least squares estimation, is developed for selecting the best predictor variables. The procedure gives an estimated prediction equation with a minimal number of predictor variables, including few interaction variables. Agronomically reasonable estimates of the regression coefficients also are obtained. Using the new procedure, a 30% reduction in the sum of squared deviations between the observed and the predicted observations compared with the stepwise regression method is found. Response curves are constructed for use in making soil test recommendations.

72-73:02G-178
COMPARATIVE YIELD AND FERTILIZER EFFICIENCY OF NO-TILLAGE AND CONVENTIONALLY TILLED CORN,
Moschler, W. W., Shear, G. M., Martens, D. C., Jones, G. D., and Wilmouth, R. R.
Virginia Polytechnic Institute and State University, Blacksburg.
Agronomy Journal, Vol. 64, No. 2, p 229-231, March-April, 1972. 3 tab, 13 ref.

Descriptors: *Cultivation, Corn, Fertilization, Fertilizers, Leaching, Nitrogen, Phosphorus, Potassium, Efficiencies.

Surface application of fertilizer for no-tillage corn is the most convenient method. The relative efficiency of fertilizer applied in this manner has been undetermined, however. Field experiments on three soil types in Virginia suggest that fertilizer efficiency for no-tillage corn with surface application was higher than for conventionally tilled corn with an equal disked-in application. No-tillage resulted in a 9-year average yield increase of 25.6% on Lodi silt loam, a 6-year average increase of 13.7% on Davidson clay loam, and a 5-year average increase of 39.0% on Cecil clay loam. In addition to increased yields, larger amounts of residual N, P, and K, as well as organic matter, were found in no-tillage soil in several cases.

72-73:02G-179
INFLUENCE OF SALINITY ON FE, MN, AND ZN UPTAKE BY PLANTS,
Maas, E. V., Ogata, G., and Garber, M. J.
United States Salinity Laboratory, Riverside, California.
Agronomy Journal, Vol. 64, No. 6, p 793-795, November-December 1972. 3 fig, 10 ref.

Descriptors: *Salinity, *Crop response, Crop production, Tomato, Soybean, Nutrients, Nutrient removal, Hydroponics.

This investigation was conducted to determine the influence of salinity on the uptake of Fe, Mn, and Zn by plants during the period of rapid vegetative growth. Relatively few data are available on the micronutrient status of salt-stunted plants. Tomato, soybean, and squash were grown in the greenhouse in half-strength Hoagland's solution salinized with 0, 25, 50, 75, and 100 meq NaCl/liter. Concentrations of Fe and Zn increased in the roots and tops of each species with increasing ambient levels of NaCl. Manganese concentrations increased in tomato and soybean tops but decreased in squash tops. Concentrations of Mn in the roots of tomato and squash were reduced at all salt levels, but they increased in all but the 100 meq/liter treatment in soybean. The changes in contents as a function of salinity were in the order of two-fold or less and all were significant at the 5% level or better.

72-73:02G-180
RESPONSE OF IRRIGATED CORN TO TIME, RATE, AND SOURCE OF APPLIED N ON SANDY SOILS,
Jung, P. E., Jr., Peterson, L. A., and Schrader, L. E.
Wisconsin University, Agronomy Department, Madison.
Agronomy Journal, Vol. 64, No. 5, p 668-679, September-October, 1972. 6 tab, 6 ref.

Descriptors: *Fertilization, *Nitrogen, *Crop response, Corn, Nutrient removal, Nitrogen compounds, Fertility.

Three sources of N were applied to corn at four rates and six times of application in all combinations. 'Wisconsin 273' and 'Wisconsin 433' corn were grown. Response was measured as grain yield, tissue yield, percentage N in tissue, percentage N in grain, and N uptake. The N applied during either the 5th, 6th, 7th, or 8th week after planting was the most effective as shown by increased grain and tissue yields. Nitrogen applied after the 8th week was associated with a distinct reduction in N uptake and grain and tissue yields. Generally, percentage N in the grain and tissue increased with later N application. Nitrate reductase (NR) activity in the leaves and percentage N in grain and tissue increased with increasing rate of applied N. Yields of grain and tissue for Wisconsin 273 and Wisconsin 433 leveled off at the 112 and 168 kg/ha rates of N, respectively.

72-73:02G-181
NITRATE-N ACCUMULATION IN THE SOIL PROFILE UNDER ALFALFA,
Schertz, D. L., and Miller, D. A.
University of Illinois, Agronomy Department, Urbana.
Agronomy Journal, Vol. 64, No. 5, p 660-664, September-October, 1972. 7 fig, 4 tab, 10 ref.

Descriptors: *Nutrient removal, *Nitrates, *Alfalfa, Leaching, Water pollution sources, Rotations, Crop production, Crop response.

Eight split applications of N totaling 0, 224, 448, and 672 kg/ha (0, 200, 400, and 600 pounds/acre) were studied at the Agronomy South Farm, Urbana, Illinois, at various depths on six sampling dates. Soil was sampled at depths of 0 to 15, 15 to 30, 30 to 60, 60 to 90, and 90 to 105 cm or to the water table, which was never lower than 105 cm. Soil samples were dried, finely ground, and analyzed for nitrate nitrogen. Nitrate nitrogen concentrations were greatest in March 1970 at the 30- to 60-cm depth. No more than 1 ppm was found at the 90- to 105-cm depth (water table) for any N treatments on November 11, 1970. Highest concentrations of nitrate nitrogen were found at the 15- to 30-cm depth for all N treatments at the end of the growing season, November 11. Although total amounts of nitrate nitrogen were lower in March than in November, the highest accumulations were found at the 30- to 60-cm depth in March, but at the 15- to 30-cm depth in November. The only treatment on November 11 that did not show a significant difference when compared to the check was the 224 kg N/ha.

72-73:02G-182
EFFECT OF HIGH RATES OF N, P, K FERTILIZER ON CORN GRAIN YIELDS,
Powell, R. D., and Webb, J. R.
Wisconsin University, Department of Soil Science, Madison.
Agronomy Journal, Vol. 64, No. 5, p 653-656, September-October, 1972. 3 fig, 4 tab, 13 ref.

Descriptors: *Fertility, *Crop response, *Corn, Nitrogen, Phosphorus, Potassium, Nutrient removal, Crop production.

Annual applications of high rates of N, P, and K fertilizer to Clarion-Webster Soil Association soils in central and north central Iowa planted to corn produced variable yield results. Incremental rates of N, P, and K fertilizers up to 1,344, 504, and 1,008 kg/ha, respectively, were applied annually for 3 consecutive years. The grain yields were analyzed statistically using analyses of variance and regression techniques. Three regression functions, a second order quadratic, a logarithmic to the base e, and a square root function were used to estimate the response surfaces and compared for goodness of fit. The yields were the dependent variable and the applied fertilizer nutrients were the independent variables.

72-73:02G-183
INFLUENCE OF SUBSURFACE BARRIER ON GROWTH, YIELD, NUTRIENT UPTAKE, AND WATER REQUIREMENT OF RICE,
Rao, K. V. P., Varade, S. B., and Pande, H. K.
Indian Institute of Technology, Department of Agricultural Engineering, Kharagpur, India.
Agronomy Journal, Vol. 64, No. 5, p 578-580, September-October, 1972. 5 tab, 7 ref.

Descriptors: *Barriers, *Rice, *Nutrient removal, Crop response, Leaching, Fertility, Fertilization, Crop production.

Growth of rice under flooded conditions in Southeast Asia results in excessive water and N losses. This investigation was conducted to determine the effect of subsurface barriers of bitumen and concrete on yields of rice grown with 60, 90, and 120 kg/ha of N. Yields of rice grown over the subsurface barriers were significantly higher than those grown on the control. The increase in growth and yield of rice was attributed to increased uptake of N, P, and Fe rendered available due to conducive redox potential. Rice produced significantly higher yields with 90 to 120 kg/ha of N than with 60 kg/ha. Subsurface barriers reduced the water requirement drastically and increased water use efficiency.

72-73:02G-184
INFLUENCE OF CROPPING SYSTEM ON SALT DISTRIBUTION IN AN IRRIGATED VERTISOL,
Hipp, B. W., and Gerard, C. J.
Texas A & M University, Agricultural Research and Extension Center, Weslaco.
Agronomy Journal, Vol. 65, No. 1, p 97-99, January-February, 1973. 3 fig, 3 tab, 6 ref.

Descriptors: *Salinity, *Leaching, Cotton, Grain sorghum, Infiltration rates, Saline water, Saline soils.

Field studies were conducted to determine the influence of cotton and grain sorghum on salt distribution in a vertisol profile. Electrical conductivity of soil saturated pastes taken from the root zone (0 to 90 cm) after 4 years of sorghum ranged from 2.6 to 4.8 mmhos/cm but ranged from 4 to 7.6 mmhos/cm at 0 to 90 cm after 4 years of cotton. Chloride concentrations showed similar trends in that Cl- concentrations were 9 to 12 meq/liter at 0 to 90 cm after sorghum, but were from 18 to 30 meq/liter at the same depth after cotton. The differences in salt concentrations in the soil profile after the two crops were attributed mainly to higher water infiltration rate after sorghum than after cotton. The data indicate that cropping practice can be an important factor in salt accumulation in clay soils and that the crops should be alternated to avoid excessive salt accumulation in the root zone.

72-73:02G-185
INFLUENCE OF FERTILIZER PLACEMENT ON YIELD RESPONSE OF SOYBEANS,
Ham, G. E., Nelson, W. W., Evans, S. D., and Frazier, R. D.
Minnesota University, Soil Science Department, Saint Paul.
Agronomy Journal, Vol. 65, No. 1, p 81-84, January-February 1973. 2 fig, 3 tab, 11 ref.

Descriptors: *Fertility, *Fertilizers, *Crop response, Nitrogen, Phosphorus, Potassium, Soybeans.

Fertilizer treatments consisting of banded starter, starter in contact with the seed, and a combination of banded and seed placement were superimposed on broadcast fertilizer treatments at three locations. Responses varied depending on environmental factors. With low rainfall and a low soil test P level, the largest response was from broadcast fertilizer. Starter fertilizer had less effect on seed yields either with or without broadcast fertilizer even though both starter and broadcast effects were significant. With adequate rainfall and a low P level, the largest response was to combinations of starter and broadcast fertilizer. Yields were increased by as much as 746, 598, and 941 kg/ha with band, seed placement and broadcast treatments, respectively. When P and K levels were very high, no yield increases were obtained from any fertilizer placement. In fact, seed placement without broadcast or seed placement and/or band in combination with broadcast decreased yields significantly in many cases.

72-73:02G-186

SIMULATION OF DROUGHT AND ITS EFFECT ON GERMINATION OF FIVE PASTURE SPECIES,

Sharma, M. L.
Commonwealth Scientific and Industrial Research Organization, Rangeland Research Unit, Riverina Laboratory, Deniliquin, New South Wales, Australia.
Agronomy Journal, Vol. 65, No. 6, p 982-987, November-December, 1973. 3 fig, 24 ref.

Descriptors: *Osmotic pressure, Drought tolerance, Dry farming, Pastures, Salinity.

While studying the effect of drought on seed germination, water potentials are usually simulated by addition of various osmotic substrates to water. Studies showing the comparative effects of these simulated water potentials of true drought are rather scarce. A study was undertaken whereby drought was simulated by sodium chloride (NaCl), mannitol, and polyethylene glycol (PEG, 20,000 mol wt.). These osmotic drought effects were compared with those of true drought. The rate and total germination of all the species declined with decreasing levels of water potential. The extent of such reduction varied considerably among species and with the type of osmotic medium. On isopotential basis, the order of osmotic medium with respect to the severity of their effect on germination reduction in all the species was PEG>NaCl>mannitol. It was suspected that both NaCl and mannitol entered the seeds, and also that the toxic effects of NaCl were either equally or dominantly offset by the solute entry effects.

72-73:02G-187

EFFECT OF TEMPERATURE AND PLANT WATER STRESS ON PHOTOSYNTHESIS DIFFUSION RESISTANCE, AND LEAF WATER POTENTIAL IN SPRING WHEAT,

Frank, A. B., Power, J. F., and Willis, W. O.
Northern Great Plains Research Center, Mandan, North Dakota.
Agronomy Journal, Vol. 65, No. 5, p 777-780, September-October, 1973. 4 fig, 3 tab, 19 ref.

Descriptors: *Soil moisture, *Crop response, *Wheat, Stress, Soil-water-plant relationships, Droughts, Salinity.

A study was conducted in growth chambers to determine the combined effects of temperature and soil water supply on the development of plant water stress and subsequent recovery in spring wheat. Measurements were made of leaf water potential, photosynthesis, and stomatal diffusion resistance on the fifth leaf at tillering and the flag leaf at heading, flowering, and grain-filling growth stages for plants grown at 10, 18, and 27C. Stomatal closure of stressed plants was affected by both leaf position and age. Closure occurred at -13, -13, and -15 bars leaf water potential at tillering and at -18, -17, and -26 bars at heading for 10, 18, and 27C, respectively. As the flag leaf matured, stomata closed at progressively lower leaf water potential. In non-stressed check plants, temperature greatly influenced leaf water potentials.

72-73:02G-188

TOLERANCE OF RICE TO SALT DURING BOOT, FLOWERING, AND GRAIN-FILLING STAGES,

Kaddah, M. T., Lehman, W. F., and Robinson, F. E.
United States Department of Agriculture, Agricultural Research Service, Imperial Valley Conservation Research Center, Brawley, California.
Agronomy Journal, Vol. 65, No. 5, p 845-847, September-October, 1973. 1 fig, 14 ref.

Descriptors: *Salinity, *Crop response, *Rice, Soil moisture, Stress, Crop production.

The effect of soil salinity on rice development at the boot, flowering, and grain-filling stages was tested for three varieties transplanted in a greenhouse. The irrigation waters used had electrical conductivities of 1.4, 3.0, and 6.0 mmho/cm at 25C. The last two irrigation waters were introduced at the three stages of development and used until harvest. Weights of grain and straw and lengths of plants and panicles did not differ significantly between the treatments, indicating that rice is not sensitive to salt after the boot stage.

72-73:02G-189

INFLUENCE OF TEMPERATURE AND MOISTURE STRESS FROM SODIUM CHLORIDE SALINIZATION ON OKRA EMERGENCE,

Albregts, E. E., and Howard, C. M.

Florida University, Agricultural Research Center, Dover.

Agronomy Journal, Vol. 65, No. 5, p 836-837, September-October, 1973. 1 tab, 7 ref.

Descriptors: *Soil moisture, *Stress, Salinity, Crop response, Crop production.

Okra seed were planted in a Scranton fine sand soil at 20, 25, and 30 C with six levels of moisture stress, 1.18, 1.75, 2.41, 4.33, 5.90, and 10.84 atm. Moisture stress was obtained by varying the moisture level in the soil and by NaCl salinization. The emergence rate and fresh plant weight decreased as the temperature decreased and soil moisture stress increased. The optimum temperature and soil moisture stress for total and earliness of emergence was 25 to 30 C and 1.18 atm. No emergence occurred at 10.84 atm of moisture stress and total emergence was reduced only at 5.90 atm and 20 C.

72-73:02G-190

RELATIONSHIP BETWEEN SOIL OXYGEN DIFFUSION RATE AND YIELD OF OATS IN A COASTAL ALLUVIAL SOIL AT CRITICAL SALINITY LEVEL,

Saini, G. R.

Research Station, Agriculture Canada, Fredericton, N. B., Canada.

Agronomy Journal, Vol. 65, No. 5, p 841-842, September-October, 1973. 1 fig, 1 tab, 7 ref.

Descriptors: *Salinity, *Oxygenation, Root distribution, Root zone, Root development.

This note reports the effect of improved soil physical conditions, as characterized by oxygen diffusion rate (ODR), on the growth of oats at the critical soil salinity level (ECe = 5.0 mmhos cm-1). In a coastal alluvial soil at critical salinity level, the yield of oats increased from 0.55 g/pot to 10.88 g/pot as ODR increased from 7.3 x 10 to the minus 8th power grams per cm squared per minute to 31.0 x 10 to the minus 8th power grams per cm squared per minute. The root elongation of the plant also appeared to be related to ODR.

72-73:02G-191

SUGARBEET RESPONSE TO IRRIGATION AS MEASURED WITH GROWTH SENSORS,

Johnson, W. C., and Davis, R. G.

United States Department of Agriculture, Southwestern Great Plains Research

Center, Bushland, Texas.
Agronomy Journal, Vol. 65, No. 5, p 789-794, September-October, 1973. 7 fig, 5 ref.

Descriptors: *Soil moisture, *Crop response, *Sugar beets, Irrigation, Irrigation practices, Growth rates.

The continuous growth records of two typical irrigated sugarbeet roots were compared at Bushland, Texas, during a 48-day period, June 25 to August 11, 1970, in a record dry season when there was little interference from rainfall on the effect of irrigation on root growth. The roots received 10 cm of irrigation water on staggered dates so that the growth record of a root not being irrigated at a particular time might be used to interpret the growth response to irrigation of the second root. The soil was slowly permeable, requiring an average of about 3 days for free water to disappear after an irrigation. A slow-growth period of about 3 days in length occurred after each irrigation during which time the irrigated root grew more slowly than the unirrigated root. When moisture stress was not extreme at the time of irrigation, a temporary decrease in growth rate actually occurred after irrigation.

72-73:02G-192
EFFECT OF NARROW TRENCHING IN HARLINGEN CLAY SOIL ON PLANT GROWTH ROOTING DEPTH, AND SALINITY,
Heilman, M. D., and Gonzalez, C. L.
United States Department of Agriculture, Agricultural Research Service, Soil, Water, and Air Sciences, Southern Region, Weslaco, Texas.
Agronomy Journal, Vol. 65, No. 5, p 816-819, September-October, 1973. 5 fig, 4 tab, 12 ref.

Descriptors: *Soil texture, *Salinity, Crop response, Cultivation, Cotton, Root zone, Root distribution.

Narrow, backfilled trenches (61 and 102 cm deep) were tested in a Harlingen clay soil as a management technique to increase rooting depth and volume of soil available to roots. Cotton was planted directly over the trenches each year for 3 years. Cotton yields were significantly increased by trenching during 1971 and 1972. Yields of 815, 995, 1163, and 1018 kg/ha were obtained during 1972 for check, 61-cm trench soil-backfilled, 61-cm trench, soil-vermiculite backfilled, and 102-cm trench soil-backfilled, respectively. Root penetration and distribution was increased from 60 cm for conventional tillage to 122 cm for 102-cm deep trenches. An average of 83% of roots for conventional tillage were in surface 30 cm as compared with 43% of 102-cm trench. Trenching increased water infiltration rates, decreased soil bulk density in trenches, and increased soil root volume available to plants.

72-73:02G-193
RAINOUT SHELTER AND DRAINAGE LYSIMETERS TO QUANTITATIVELY MEASURE DROUGHT STRESS,
Teare, I. D., Schimmelpfennig, H., and Waldren, R. P.
Kansas State University, Evapotranspiration Laboratory, Manhattan.
Agronomy Journal, Vol. 65, No. 4, p 544-547, July-August, 1973. 7 fig, 2 ref.

Descriptors: *Lysimeters, *Drainage, Stress, Droughts, Drought tolerance.

A modern rainout shelter designed to open and close with an improved electronic control system and to withstand high winds is described. It was installed in conjunction with drainage lysimeters to quantitatively evaluate evapotranspiration, physiological indicators of drought stress, and irrigation scheduling.

72-73:02G-194
A RESISTANCE MODEL TO PREDICT EVAPOTRANSPIRATION AND ITS APPLICATION TO A SUGAR BEET FIELD,
Brown, K. W., and Rosenberg, N. J.
Texas A & M University, Soil and Crop Sciences Department, College Station.
Descriptors: *Evapotranspiration, *Measurement, *Sugar beets, Mathematical models, Computer models, Soil moisture.

A method is needed to extrapolate the detailed micrometeorological and lysimetric determinations of evapotranspiration and its dependence on the microclimate and crop factors to fields where such detailed measurements are not made. The dependence of latent heat flux from a crop on crop resistance, air resistance, air temperature, water vapor pressure, and net radiation minus soil heat flux was evaluated by means of an electrical resistance analogue of the transfer process and by means of an energy balance equation. The difficulties inherent in the application of the model to both the single leaf and the crop are discussed. The major difficulty in applying the resistance model to a field crop may be that the sinks and sources of latent and sensible heat flux may not be identical within the crop. Hourly LE predicted by the model and determined by the energy balance generally agreed within 5%. Daily totals of LE, evaluated by the two methods, agreed well on all occasions.

72-73:02G-195
SALT TOLERANCE OF CHICKPEA VARIETIES DURING GERMINATION,
Kheradnam, M., and Ghorashy, S. R.
Pahlavi University, Department of Agronomy, Shiraz, Iran.
Agronomy Journal, Vol. 65, No. 2, p 329, March-April, 1973. 1 fig, 8 ref.

Descriptors: *Salinity, *Crop response, Germination, Osmotic pressure, Crop production, Yield equations.

Effects of seven salinity levels (0 to 2% NaCl) on germination of Iranian chickpea varieties, 'Isfahan 11,' 'Ardebill 169,' 'Ardebill 174,' and 'Ahar 174' were determined under controlled temperature (30 ± 2 C). Increased salinity reduced the germination of Isfahan 11 significantly more than Ardebill 174 and Ahar 174. Sodium chloride concentrations greater than 0.5% reduced the germination of all varieties significantly. Ghe general trend in germination reduction with increased salinity was the same for each variety.

72-73:02G-196
RESPONSE OF THREE CORN HYBRIDS TO LOW LEVELS OF SOIL MOISTURE TENSION IN THE PLOW LAYER,
Rhoads, F. M., and Stanley, R. L., Jr.
Agricultural Research and Education Center, Quincy, Florida.
Agronomy Journal, Vol. 65, No. 2, 315-318, March-April, 1973. 3 fig, 3 tab, 9 ref.

Descriptors: *Irrigation, *Irrigation practices, *Crop response, Tensiometers, Soil moisture, Tension, Fertility.

The objective was to evaluate the response of three corn hybrids to irrigation treatments that were designed to maintain soil moisture tension at low levels in the plow layer rather than the entire root zone. Flowering date, plant height, and grain yield were used as indexes of response. Irrigation was applied at four levels (0.3, 0.6, 2.0, and 5.0 bars) of soil moisture tension in 1970 and at three levels in 1971. Nitrogen was applied at 336 and 560 kg/ha, in 1971, to treatments irrigated at 0.2 bar of soil moisture tension. Each irrigation treatment was replicated four times and consisted of applying water at a selected value of soil moisture tension. A tensiometer was placed in each plot to be irrigated at soil moisture tensions below 1 bar in order to monitor soil moisture tension at a depth of 15 cm. Electrical resistance units were used in 1970 to monitor soil moisture tension in plots irrigated at tensions above 1 bar.

72-73:02G-197
WATER RELATIONS AND GROWTH OF COTTON IN DRYING SOIL,
Klepper, B., Taylor, H. M., Huck, M. G., and Fiscus, E. L.
Auburn University, Department of Botany and Microbiology, Alabama.
Agronomy Journal, Vol. 65, No. 2, p 307-310, March-April, 1973. 5 fig, 1 tab, 17 ref.

Descriptors: *Irrigation, *Soil moisture, *Crop response, Cotton, Transpiration, Root development, Root systems, Diurnal.

Two 70-day-old cotton plants were subjected to a 26-day drying cycle at the Auburn rhizotron in order to quantitatively study water relations and growth of both root and shoot as the soil dried. Measurements were made of rooting density changes; stem diameter and height increase; and soil water content, soil water potential, and plant water potential. Marked diurnal fluctuations in plant hydration and soil water potential were observed, especially during the middle of the drying cycle. Plant height increase and stem diameter growth slowed drastically after 17 days even though 35% of the root system was in soil wetter than -1 bar and the plant was rehydrating to a water potential of -3 to -5 bars. Plant water potential in the early morning did not equilibrate with the water potential of the wettest horizon of soil.

72-73:02G-198
EFFECT OF POROUS ROOTZONE MATERIALS UNDERLINED WITH PLASTIC ON THE GROWTH OF CREEPING BENTGRASS,
Ralston,D. S., and Daniel, W. H.
Miller, Wihry and Brooks, Louisville, Kentucky.
Agronomy Journal, Vol. 65, No. 2, p 229-232, March-April, 1973. 5 fig, 2 tab, 7 ref.

Descriptors: *Soil moisture, *Crop response, *Grasses, Perched water, Plastics, Tension, Pore water,Porosity.

Creeping bentgrass was studied under putting green conditions when grown on replicated plastic-lined plots containing dune sand, mortar sand, calcined clay, diatomaceous earth, and peat. Soil was not included in any of the rootzone mixtures because of its inherent structural instability. In 1968 and 1969, some infiltration rates exceeded 150 cm/hr and all were greater than 7 cm/hr, therefore, water movement was considered ample. The relative ability of the material in plots to retain moisture was measured by allowing the plots to dry-down for 15 days between rains during August 1968 and for 17 days during July 1969. No irrigation was added to any plot until turf showed severe wilt. Bentgrass on plots containing the finer fractions of the dune sand, diatomaceous earth, various mixtures of sand, calcined aggregates, and peat did not require water for either period.

72-73:02G-199

EFFECTS OF SUBSURFACE ASPHALT LAYERS ON CORN AND TOMATO ROOT SYSTEMS,

Saxena, G. K., Hammond, L. C., and Robertson, W. K.
Florida University, Soil Science Department, Gainesville.
Agronomy Journal, Vol. 65, No. 2, p 191-194, March-April, 1973. 3 fig, 2 tab, 13 ref.

Descriptors: *Root systems, *Root zone, *Asphalt, Barriers, Root distribution, Corn, Tomatoes, Crop response.

This study was initiated to determine the nature and reason of any influence of a subsurface asphalt layer on root growth and distribution in the soil profile. Observations of root distributions of sweet corn and tomato were made in freshly dug pits. Root sections in and out of the asphalt layer were photographed and examined microscopically for morphological effects. The "line-intercept" method was used to obtain quantitative measurements of root concentration of field corn. Tomato roots in the asphalt layer were larger in diameter and showed damage to cells in the cortex. Rooting of all crops was less extensive in soil below the asphalt layer than in soil at the same depth without the asphalt. Concentration of corn roots in the top 60 cm of soil averaged 1.6, 1.7, 2.0, and 2.2 cm/cc for the following respective treatments: control, control with irrigation, asphalt layer, and asphalt layer with irrigation.

72-73:02G-200

EFFECTIVENESS OF TWO NITRIFICATION INHIBITORS FOR ANHYDROUS AMMONIA UNDER IRRIGATED AND DRYLAND CONDITIONS,

Cochran, V. L., Papendick, R. I., and Woody, W. M.
United States Department of Agriculture, Agricultural Research Service, Western Region, Pullman, Washington.
Agronomy Journal, Vol. 65, No. 4, p 649-653, July-August, 1973. 5 fig, 15 ref.

Descriptors: *Nitrogen, *Nitrification, *Leaching, Ammonia, Nitrogen cycle, Nitrogen fixation, Wheat.

Potassium azide and 2-chloro-6-(trichloromethyl) pyridine were evaluated as nitrification inhibitors for anhydrous NH3 field applied on irrigated and nonirrigated Ritzville silt loam and on nonirrigated Naff silt loam in eastern Washington. Formulations of KN3, N-Serve in liquid NH3, or NH3 alone were applied to fallow soil in midsummer at a rate of 90 kg N/ha. Irrigations were 15 cm of water sprinkler applied 1 day or 2 weeks after fertilizer application, and 10 to 15 cm of water each time at 4, 8, and 13 weeks after NH3 application. The NH3 retention zone was sampled for NH+4 and NO-3 periodically through December for the Naff soil and through February for the Ritzville soil. Both KN3 and N-Serve effectively inhibited nitrification of the applied NH3 on nonirrigated Ritzville soil when temperature and soil moisture were favorable for rapid nitrification. However, KN3 was completely ineffective following irrigation or, for the Naff soil, after rainwater penetrated below the retention zone 2 weeks after N application.

72-73:02G-201

EFFECT OF SOIL MOISTURE DURING EARLY STAGES OF DEVELOPMENT ON GROWTH AND YIELD OF COTTON PLANTS,

Marani, A., and Levi, D.
Hebrew University of Jerusalem, Faculty of Agriculture, Rehovot, Israel.
Agronomy Journal, Vol. 65, No. 4, p 637-641, July-August, 1973. 7 fig, 2 tab, 11 fig.

Descriptors: *Irrigation, *Irrigation practices, *Cotton, Crop response, Soil moisture, Crop production, Tension.

The effect of three irrigation treatments on the vegetative development of two cultivars of upland cotton was studied in two experiments conducted under different climatic conditions. The treatments differed until the middle of flowering and were designated as L (no irrigation), M (regular), and H(early and excessive irrigation). From mid-flowering onwards all plots were irrigated regularly. In both experiments, treatment L resulted in a slower growth rate, smaller plants, fewer nodes and fruiting branches, and smaller leaf area index (LAI), and dry matter (DM) weight throughout the season. Small differences were found between the effects of treatments M and H. No excessive vegetation development was observed in this study. The highest rates of DM production were associated with LAI values between 2.0 and 3.0 A close relationship was found between lint yield, Dm production and leaf area duration.

72-73:02G-202

WATER STRESS RELATIONS OF THE POTATO PLANT UNDER FIELD CONDITIONS,

Epstein, E., and Grant, W. J.
United States Department of Agriculture, Agricultural Research Service, Orono, Maine.
Agronomy Journal, Vol. 65, No. 3, p 400-404, May-June, 1973. 9 fig, 15 ref.

Descriptors: *Soil moisture, *Crop response, *Potatoes, Water requirements, Water utilization, Stress.

Potatoes grown in northern Maine are often subjected to extensive periods of drought. The objective of this study was to examine the physiological response of potatoes to soil water stress. Relative water content, leaf diffusive resistance, and tuber water potential of two potato varieties were measured under irrigated and nonirrigated conditions. There were pronounced differences in relative water content, leaf diffusive resistance, and tuber water potential as a result of irrigation. Relative water content (RWC) of plant leaves correlated well with soil water potential but poorly with leaf diffusive resistance. The two potato varieties differed in RWC when soil water potential was high. Tuber water potential correlated well with RWC and soil water potential. Similarity between tuber water potential and the RWC data suggested that the potato plant exhibits water stress when the soil water potential drops below -0.25 bar.

72-73:02G-203

WATER LOSS FROM AN IRRIGATED SORGHUM FIELD: II. EVAPOTRANSPIRATION AND ROOT EXTRACTION,

Stone, L. R., Horton, M. L., and Olson, T. C.
South Dakota State University, Plant Science Department, Brookings.
Agronomy Journal, Vol. 65, No. 3, p 495-497, May-June, 1973. 5 fig, 9 ref.

Descriptors: *Drainage, *Evapotranspiration, *Deep percolation, Soil water, Soil moisture, Tensiometers, Soil water movement.

A method using tensiometers for obtaining evapotranspiration rates and root extraction patterns within an actively growing sorghum crop is discussed. Profile water depletion was calculated from water content profiles determined using tensiometer readings and laboratory-measured soil water characteristics. Profile water depletion minus flux below the root zone yielded the daily evapotranspiration rate. During the 31-day study, approximately 65% of the total water loss was due to flux loss from the root zone. These data clearly show the importance of considering flux below the root zone when attempting to determine evapotranspiration rates using depletion methods. The method of determining evapotranspiration rates illustrated in this paper provides an alternative to the microclimatological and lysimeter methods.

72-73:02G-204

COTTON LEAF TEMPERATURES AS RELATED TO SOIL WATER DEPLETION AND METEOROLOGICAL FACTORS,

Ehrler, W. L.

United States Water Conservation Laboratory, Phoenix, Arizona.

Agronomy Journal, Vol. 65, No. 3, p 404-409, May-June, 1973. 4 fig, 3 tab, 9 ref.

Descriptors: *Irrigation, *Irrigation practices, *Crop response, Cotton, Soil moisture, Tension.

In two field experiments with cotton, the relation between moderate soil water depletion and leaf-air temperature difference (Delta T) was investigated for feasibility of measurement and possible use as a guide to irrigation scheduling. Hourly temperatures of the upper leaves and of the air 1 m above the canopy were obtained for three cultivars of short-staple cotton and one of long-staple. In addition, hourly measurements were made of the vapor pressure 1 m above the crop. These data were taken during six irrigation cycles extending over two summers and encompassing a wide range of saturation deficit (SD). The temperature differences were measurable and predictable. When the SD remained steady from day to day, the mean daytime Delta T decreased 1 C on the day of irrigation and an additional degree the next day owing to leaf rehydration and consequent stomatal opening.

72-73:02G-205

IONIC BALANCE FOR BARLEY AS INFLUENCED BY P FERTILITY, WATER, AND SOIL TEMPERATURE,

Follett, R. F., and Reichman, G. A.

United States Department of Agriculture, Northern Great Plains Research Center, Mandan, North Dakota.

Agronomy Journal, Vol. 65, No. 3, p 477-482, May-June, 1973. 4 fig, 1 tab, 23 ref.

Descriptors: **Nutrient removal, *Leaching, *Phosphorus, Barley, Ion transport, Fertility, Fertilizers.

The relationship between organic anion concentration and yield of spring barley was investigated in a growth room at three levels of P. This relationship was tested at three levels of available soil water (W) and three soil temperatures (T). The concentration of organic anions was determined as the difference between the sum of the meq/kg of inorganic cations and the sum of the meq/kg of inorganic anions. A normal organic anion (C-A) concentration was considered to be that giving optimal growth. In this study, P was more important for obtaining a normal (C-A)than either W or T. Phosphorus increased yields, decreased (C-A) to near normal, and decreased the adverse effects of low W and low T. The large differences in (C-A) between treatments suggests that, under adverse conditions, organic anions may serve as reservoirs of useful metabolites.

72-73:02G-206

WATER LOSS FROM AN IRRIGATED SORGHUM FIELD: I. WATER FLUX WITHIN AND BELOW THE ROOT ZONE,

Stone, L. R., Horton, M. L., and Olson, T. C.
South Dakota State University, Plant Science Department, Brookings.
Agronomy Journal, Vol. 65, No. 3. p 492-495, May-June, 1973. 5 fig, 1 tab, 6 ref.

Descriptors: *Soil water, *Soil moisture, *Leaching, Tensiometers, Hydraulic gradient, Hydraulic conductivity.

This work was done to evaluate water movement within and below the root zone of a sorghum crop during a 31-day field study following water application. Hydraulic potential data from tensiometers placed at eight depths in the soil profile were used to determine the hydraulic gradients. Soil water flux in various depth layers was calculated using the hydraulic potential gradients and the determined hydraulic conductivity vs soil water content relationships. Upward water movement commenced in the 15 to 30 cm layer 3 days following water application and 130 to 150 cm layer after 19 days. The upward water flux into the root zone reached a maximum of approximately 0.2 cm/day near the end of the study period. During the 31-day study period, 6.0 cm of water were lost from the 150 cm soil profile by flux below the root zone. This illustrates the importance of considering water loss due to flux below the root zone in crop situations.

72-73:02G-207

YIELD RESPONSE OF SOYBEAN VARIETIES GROWN AT TWO SOIL MOISTURE STRESS LEVELS,

Mederski, H. J., and Jeffers, D. L.
Ohio Agricultural Research and Development Center, Wooster.
Agronomy Journal, Vol. 65, No. 3, p 410-412, May-June, 1973. 2 tab, 12 ref.

Descriptors: *Irrigation, *Irrigation practices, Soil moisture, Crop response, Soybeans, Stress, Droughts.

Eight soybean varieties in each of four maturity groups were grown to maturity at optimum and deficient soil moisture conditions to determine differences in varietal response to soil stress. A significant variety by stress level interaction on seed yield was detected among varieties in each of four maturity groups, indicating that the effect of soil moisture stress on yield varied among varieties. Under high moisture stress conditions, the yield of the most stress resistant varieties was reduced about 20%, while the yield of the least stress-resistant varieties was reduced about 40%. Under conditions of optimum soil moisture, the difference in yield among varieties was large relative to the difference in yield produced under dificient moisture conditions. A low or nonstress soil moisture level permits greater genotypic expression, thereby increasing genotypic variance among varieties. A low soil moisture stress environment appears to be the optimum environment for selecting soybean yield attributes.

72-73:02G-208

EFFECT OF SUPPLEMENTAL WATER ON BARLEY AND CORN PRODUCTION IN A SUBHUMID REGION,

Power, J. F., Bond, J. J., Sellner, W. A., and Olson, H. M.
United States Department of Agriculture, Northern Great Plains Research Center, Mandan, North Dakota.
Agronomy Journal, Vol. 65, No. 3, p 464-467, May-June, 1973. 1 fig, 4 tab, 6 ref.

Descriptors: *Irrigation, *Irrigation practices, *Supplemental irrigation, Irrigation programs, Irrigation effects, Corn, Barley.

A 3-year field experiment was conducted on a loam soil in eastern North Dakota to determine the effect of supplemental water, added in various quantities and at different times, on malting barley and corn silage production. Irrigation consisted of (a) none; (b) after previous harvest only (to fill 120-cm profile); (c) 6 cm applied per irrigation as needed during growing season; (d) after previous harvest plus 6 cm at anthesis; (e) after previous harvest plus 6 cm applied as needed during the growing season; and (f) after previous harvest plus 9 to 12 cm applied as needed during the growing season. Water added after harvest was not reflected in soil water content by seeding time the following spring or in increased crop yields, indicating that fall irrigation was of little value. A linear regression existed between total water use and both barley grain and corn silage production, with no distinct differences between the six water treatments evident.

72-73:02G-209

NITROGEN METABOLISM OF STARGRASS AS AFFECTED BY NITROGEN AND SOIL SALINITY,

Langdale, G. W., Thomas, J. R., and Littleton, T. G.
United States Department of Agriculture, Watkinsville, Georgia.
Agronomy Journal, Vol. 65, No. 3, p 468-470, May-June, 1973. 3 fig, 2 tab, 19 ref.

Descriptors: *Fertility, *Nitrogen, Fertilizers, Salinity, Nutrient removal, Leaching, Crop response.

Interactive effects of soil salinity and N fertilizer on stargrass growth and N metabolism were investigated. Nitrogen contents were partitioned to study the effects of substrate salinities on hydrolysis of protein-N and the accumulation nonprotein-N assimilates. Mixed chloride-sulfate solutions of the same ionic ratios and electrical conductivities (EC) of 4.8, 9.6, and 14.4 mmhos/cm were equilibrated with Brennan fine sandy loam soil, after which N was applied in a factorial arrangement at rates of 0, 67, 133, and 200 mg/kg of soil. Nitrogen fertilizer interacted significantly with soil salinity to stimulate dry matter and protein-N yields at the 4.8-mmhos/cm level. No evidence of a toxic nonprotein-N accumulation in plant tissue was observed even with high N fertilization at this salinity level. The 9.6-mmhos/cm salinity treatment was considerably more deleterious to dry matter than to protein-N production processes.

72-73:02G-210

INFILTRATION AND ROOT EXTRACTION FROM SUBSURFACE IRRIGATION LATERALS,

Gilley, J. R., and Allred, E. R.
Minnesota University, Agricultural Engineering Department, Saint Paul.
Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 27 p, 11 fig, 4 tab, 29 ref.

Descriptors: *Irrigation, *Subsurface irrigation, Irrigation practices, Soil moisture, Soil water movement, Soil physics.

An analytical solution to the soil moisture flow equation was used to simulate flow in partially saturated soils during steady infiltration from buried line sources. A series of plane sinks was used to model water consumption by plants. The resulting model was used to determine optimum lateral placement to obtain desired crop extraction patterns.

72-73:02G-211
A COMPUTER MODEL FOR PREDICTING NITRATE AND OTHER SOLUTES OF AGRICULTURAL DRAIN WATER,
Dutt, G. R., and Saffer, M. J.
Arizona University, Department of Soils, Tucson.
Final report on Contract No. 14-06-D-7328, United States Bureau of Reclamation, Denver, Colorado, June, 1972. 29 p, 4 fig, 2 append.

Descriptors: *Drainage, *Soils, Reclamation, Water quality, Pollutants, Systems analysis, Computer models.

A computer simulation model was developed for predicting the changes in solute composition due to chemical reactions in the saturated region below the water table for tile drain systems underlaid by an impermeable layer. The ionic species considered to be present in the water include Ca++, Mg++, Na+, NH4+, SO4=, CI-, HCO3-, CO3=, and NO3-. Chemical reactions considered are base exchange, dissociation or precipitation of gypsum and lime (CaCO3), and reactions between Ca and Mg of sulfate ion pairs in solution. Verification of the model is considered. A procedure for utilizing the above with other models previously developed by the authors and others is outlined. It is concluded that the procedure developed is suitable for practical application to base saturated soils fitting the boundary conditions. The procedure can be expanded to consider other soils and interactions which may be found to be of importance at a later date.

72-73:02G-212
DRAINAGE OBSERVATIONS IN LATIN AMERICA,
Christiansen, J. E.
Utah State University, Agricultural and Irrigation Engineering Department, Logan.
Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 4 p.

Descriptors: *Drainage, *Surface drainage, *Subsurface drainage, Tile drainage, Salinity, Water table, Soil water movement, Saline soils.

Although there are many excellent irrigation systems in most of the Latin American countries, the problem of drainage and salinity generally has been neglected. There are many areas where, because of lack of adequate natural drainage, high water tables and acute salinity conditions have developed.

72-73:02G-213
SIMULATION MODEL FOR EVALUATING IRRIGATION MANAGEMENT PRACTICES,
Morey, R. V., and Gilley, J. R.
Minnesota University, Agricultural Engineering Department, Saint Paul.

Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 14 p, 8 fig, 1 tab, 16 ref.

Descriptors: *Irrigation practices, *Computer models, Mathematical models, Irrigation, Irrigation systems, Irrigation effects, Soil moisture, Crop response.
Identifiers: Irrigation Management.

A soil moisture budget which can be used to evaluate irrigation management practices is presented. Results of a calibration-verification procedure are included. The model is used to test several irrigation management policies for two soil types and 24-years of weather data for St. Cloud, Minnesota.

72-73:02G-214
DRAINAGE INVESTIGATIONS AND FINDINGS ON THE GOTVAND PROJECT - IRAN,
Jacobsen, P.
Harza Engineering Company, Chicago, Illinois.
Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-15, 1972. Chicago, Illinois. 7 p, 3 fig, 2 tab, 3 ref.

Descriptors: *Drainage, *Surface drainage, *Subsurface drainage, Tile drainage, Soil water, Salinity, Water table.

In the spring of 1972 a special drainage investigation, which included soil analyses and permeability studies, was made on the Gotvand Project in Iran. As a result, drainage recommendations were made for specific areas and a monitoring system was proposed that would indicate the need for additional drainage before land damage can occur.

72-73:02G-215
DRAINAGE AND WATER MANAGEMENT IN HUNGARY,
Donnan, W. W., and Jaranyi, G.
United States Department of Agriculture, Agricultural Research Service, Riverside, California.
Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-15, 1972. Chicao, Illinois. 9 p, 5 ref.

Descriptors: *Drainage, *Water management (applied), Surface drainage, Subsurface drainage, Tile drainage, Irrigation practices, Irrigation systems.

Hungary has enbarked on an ambitious program to develop its soil and water resources. This paper details some of the progresses to date with emphasis on the work in the drainage field.

72-73:02G-216
COMPARISON OF DRAINAGE METHODS IN A HEAVY-TEXTURED SOIL,
Schwab, G. O., Fausey, N. R., and Michener, D. W.
Ohio Agricultural Research and Development Center.
Presented at Winter Meeting of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 5 p, 1 tab, 6 ref.

Descriptors: *Drainage, Surface drainage, Subsurface drainage, Tile drainage, Crop response, Soil water, Drainage engineering, Soil water movement.

Corn, Oat, and soybean yields from surface drained, tile drained, and a combination of tiled and surface drained plots in northern Ohio were obtained over a 10-year period. Both conventional tillage and no tillage practices were included. Rainfall plus irrigation and drainage flow effects on yields were studied.

72-73:02G-217
LAND DRAINAGE OF REDDISH CLAY LOAMS,
Massie, L. R., and Tenpas, G. H.
Wisconsin University, Madison.
Presented at Winter Meeting of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 8 p, 1 fig, 5 tab.

Descriptors: *Drainage, Surface drainage, Subsurface drainage, Tile drainage, Crop response, Soil water, Drainage engineering, Soil water movement.

An excellent forage can be established and maintained by providing a drainage system (surface and/or tile), fertility, and selecting varieties carefully.

72-73:02G-218
DEVELOPMENT OF BI-LEVEL DRAINAGE THEORY,
DeBoer, D. W., and Chu, S. T.
South Dakota State University, Brookings.
Presented at Winter Meeting of the American Society of Agricultural Engineers, December 11-15, Chicago, Illinois. 12 p, 4 fig, 6 ref.

Descriptors: *Drainage, Surface drainage, Subsurface drainage, Tile drainage, Crop response, Soil water, Drainage engineering, Soil water movement.

Two analytical solutions were derived for the bi-level drainage problem. The two solutions, based on the Dupuit-Forchheimer assumptions, are for the steady state and falling water table conditions. These solutions should be applicable to the design of subsurface drainage systems with drain lines at two elevations on an alternating basis.

72-73:02G-219
EFFECT OF SURFACE DRAINAGE ON WATER TABLE RESPONSE TO RAINFALL,
Skaggs, R. W.
North Carolina State University, Department of Biological and Agricultural Engineering, Raleigh.
Presented at Winter Meeting of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 23p, 10 fig, 4 tab, 15 ref.

Descriptors: *Drainage, *Surface drainage, Crop response, Soil water, Water table, Rainfall, Soil water movement, Drainage engineering.

A method for determining the effect of surface drainage on the water table response to rainfall is presented and used to predict water table rise on a Lumbee sandy loam. Predicted results were in good agreement with actual measurements. Approximate methods for implementing the method are presented and discussed.

72-73:02G-220
QUALITY OF DRAINAGE WATER FROM A HEAVY-TEXTURED SOIL,
Schwab, G. O., McLean, E. O., Waldron, A. C., White, R. K., and Michener, D. W.
Ohio State University, Department of Agricultural Engineering, Columbus.
Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 13 p, 2 fig, 4 tab, 11 ref.

Descriptors: *Drainage, *Subsurface drainage, Tile drainage, Water quality, Salinity, Water chemistry, Ion transport.

Sediment, dissolved solids, nine chemical elements or ions, five pesticides, electrical conductivity, pH, and BOD in tile effluent and in surface runoff were measured from field plots in Toledo silty clay soil near Sandusky, Ohio, for the period 1969-71. Measurements were taken from both conventional tilled and no tilled plots in continuous corn. Laboratory studies were also made on phosphorus movement.

72-73:02G-221
SUBSURFACE IRRIGATION IN HAWAIIAN SUGARCANE,
Vaziri, C. M.
Hawaiian Sugar Planters' Association Experiment Station, Honolulu, Hawaii.
Presented at Winter Meeting of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 11 p, 6 fig, 5 tab.

Descriptors: *Irrigation, *Subsurface irrigation, Irrigation practices, Sugarcane, Hawaii, Irrigation engineering.

The first successful subsurface irrigation system for sugarcane was installed on March 29, 1970, at HSPA Kunia Substation in an 8,000 square foot area. The field was harvested on November 3, 1971. After harvest, the system was inspected and found to be functioning adequately. Field results indicate water savings and yield increase.

72-73:02G-222
DYNAMIC SIMULATION OF AUTOMATED SUBSURFACE IRRIGATION SYSTEMS,
van Bavel, C. H. M., Ahmed, J., Bhuiyan, S. I., Hiler, E. A., and Smajstrla, A. G.
Texas A & M University, Soil and Crop Sciences Department, College Station.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 6, p 1095-1099, November-December, 1973. 6 fig, 1 tab, 6 ref.

Descriptors: *Irrigation practices, *Subsurface irrigation, Automation, Computer models, Mathematical models, Soil moisture, Soil water, Soil water movement.

Water delivery and distribution from a subsurface irrigation system were simulated for a simplified one-dimensional case. Water loss by surface evaporation and root uptake was taken into account in a manner reflecting its dependence upon depth and time of day. The system was defined as an automatic one, in which the water content at a given depth would turn infiltration from the buried delivery system off and on. The simulation was performed in S/360 CSMP, a dynamic simulation language that appears well adapted for this type of problem. The program is efficient and allows ready substitution of the hydraulic characteristics of the soil, the consumptive use pattern, and the root uptake distribution with depth, as well as geometrical variables. The results suggest that in a Yolo clay loam and with a typical consumptive use and root distribution pattern, an automated system will cycle from a delivery period of about 2 hours through a redistribution period of about 40 hours, while maintaining an essentially constant water content in the root zone, provided the depth of delivery and control are properly chosen.

72-73:02G-223
INFILTRATION AND WATER TABLE EFFECTS OF SOIL AIR PRESSURE UNDER BORDER IRRIGATION,
Linden, D. R., and Dixon, R. M.
United States Department of Agriculture, Agricultural Research Service, Reno, Nevada.
Soil Science Society of America Proceedings, Vol. 37, No. 1, p 94-98, January-February, 1973. 7 fig, 11 ref.

Descriptors: *Irrigation, *Infiltration, Infiltration rates, Surface irrigation, Border irrigation, Soil moisture.

Field studies investigated infiltration and water table responses to soil air pressure under border irrigation. The water table was depressed in the center and elevated near the edge of a border strip in response to differences in soil air pressure during an irrigation. Also, water table elevations indicated that infiltration and subsequent groundwater recharge rates were greater in the vicinity of a border dike than at the center of the border. An infiltration response was measured by: (i) venting soil air during an actual irrigation and (ii) pumping air into the soil during simulated irrigations. An actual border irrigation experiment indicated that displaced soil air pressure ha rising to values of 13 to 24 cm of H2) reduced infiltration over a 70-minute period from 14.3 to 10.3 cm. Simulated border irrigation experiments indicated that displaced soil air pressure ha must exceed surface head hs to have significant influence on infiltration and that the first few minutes of infiltration may determine the ha-to-hs relationship and subsequent infiltration effects.

72-73:02G-224
EFFECT OF IRRIGATION FREQUENCY ON THE AVERAGE EVAPOTRANSPIRATION FOR VARIOUS CROP-CLIMATE-SOIL SYSTEMS,
Norero, A. L., Keller, J., and Ashcroft, G. L.
Universidad Catolica, Santiago, Chile.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 662-666, July-August, 1972. 6 fig, 1 tab, 23 ref.

Descriptors: *Irrigation, *Irrigation practices, *Irrigation engineering, Evapotranspiration, Water utilization.

The general relationship between ETRa and the time since the root zone soil moisture has been completely replenished was developed and discussed. Examples were given and the final development of ETRa versus t curves were produced from field crop data found in the literature. The data selected were for corn grown in shallow field lysimeters and deep rooted field alfalfa to demonstrate rather extreme cases in terms of the irrigation frequency required to maintain a high ETRa or relative productivity.

72-73:02G-225
EFFECT OF ION-PAIR FORMATION ON THE SOLUBILITY PRODUCT.
Babcock, K. L., and Marion, G. M.
California University, Department of Soils and Plant Nutrition, Berkeley.
Soil Science Society of America Proceedings, Vol. 36, No. 4, p 689-691, July-August, 1972. 4 ref.

Descriptors: *Ions, Ion exchange, Solubility, Gypsum, Soil chemistry.

Two treatments of electrolyte solutions in which ion-pair formation occurs are possible: one as a strong electrolyte, the other as a weak electrolyte. It is demonstrated, however, that the value of a solubility product is independent of the method of treatment.

72-73:02G-226
RESIDUAL EFFECTS OF N15-LABELED FERTILIZERS IN A FIELD STUDY,
Westerman, R. L., and Kurtz, L. T.
Illinois University, Department of Agronomy, Urbana.
Soil Science Society of America Proceedings, Vol. 36, No. 1, p 91-94, January-February, 1972. 1 fig, 3 tab, 6 ref.

Descriptors: *Nutrient removal, *Nitrogen, *Leaching, Crop production, Crop response, Crops, Denitrification, Radioisotopes.

Residual effects of two N15-labeled N fertilizers, urea and oxamide, were compared during the second cropping season after they had been applied at rates of 0, 56, 112, and 168 kg N/ha. 'Sudax SX11' sorghum-sudan grass hybrid was grown and harvested three times during this second cropping season while the residual effects were being measured. Fertilizer N removed in plant tops during this second year of cropping contained 13-18% of the residual fertilizer N in the soil at the end of the first season and was equal to 4-6% of that applied originally in the fertilizers. At the end of the second cropping season, 22 and 26% of the initial applications of N in urea and oxamide, respectively, remained in the soil. The effect of carriers on these amounts of residual fertilizer N was not significant. The removals in crops during the second season were essentially equal to the residual fertilizer N which had been in the soil at the end of the first season.

72-73:02G-227
SOIL MULCH EFFECTS ON SEEDBED TEMPERATURE AND WATER DURING FALLOW IN EASTERN WASHINGTON,
Papendick, R. I., Lindstrom, M. J., and Cochran, V. L.
United States Department of Agriculture, Agricultural Research Service, Pullman, Washington.
Soil Science Society of America Proceedings, Vol. 37, No. 2, p 307-314, March-April, 1973. 8 fig, 1 tab, 23 ref.

Descriptors: *Mulching, *Dry farming, Wheat, Temperature, Thermal insulation, Cultivation, Unsaturated flow, Evaporation.

Depth of dry soil mulch affected summer soil temperatures and seed-bed water at the end of fallow in the dryland wheat region of eastern Washington. Increasing the depth of the tillage mulch from 6 to 11 cm reduced summertime seed zone drying sufficiently to benefit wheat emergence. Reduction of drying was greatest when the seed zone had good capillary continuity with the deeper soil layers. Drying depth and intensity was greater with a cloddy soil mulch than with a fine mulch. The seed zone water-conserving effect of a fine soil mulch was related to the lowered temperatures and temperature gradients across the seed zone associated with the increased mulch depth. The deeper soil mulch conserved seedbed water through increased resistance to water flow from moist layers to the atmosphere, and through increased thermal insulation of the moist soil below the dry mulch. Surface-applied straw decreased seed-zone temperatures under the shallow mulch only.

72-73:02G-228
RESPONSE OF CORN TO TIME AND RATE OF PHOSPHORUS AND ZINC APPLICATION,
Keefer, R. F., Singh, R. N., Horvath, D. J., and Henderlong, P. R.
West Virginia University, Plant Sciences Division, Morgantown.
Soil Science Society of America Proceedings, Vol. 36, No. 4, p 628-632, July-August, 1972. 5 fig, 8 tab, 23 ref.

Descriptors: *Nutrients, *Corn, *Crop response, Phosphorus, Zinc, Soil chemistry, Fertility, Fertilization.

Corn was grown in the greenhouse on two soils - Monogahela, a Typic Fragiudult (I) and Wharton, an Aquic Hapludult (II), which differed in available Zn, available P, exchangeable Mg, total Zn, and organic matter (OM). Dry matter yield and Zn concentration and content of plant parts were increased where Zn either as ZnSO4 or ZnEDTA was applied with P regardless of time to soil I. Zinc-EDTA seemed to be a better source of Zn since it increased Zn concentration in leaves and stems more than ZnSO4 on soil I. However, with soil II, response to ZnSO4 application was obtained only when P was applied at high rates 8 weeks before planting. Application of ZnEDTA produced no significant response by corn on soil II, probably due to instability of ZnEDTA under acid conditions resulting in appreciable amounts being fixed on clays in this soil. The relative response to Zn with increasing levels of P was greater on soil I than on soil II. Addition of Zn in the former decreased the percent P and P content in both leaves and stems at high levels of P application; however, application of Zn to all the latter did not show any noticeable affect on percent P at all levels of P application.

Section VIII

WATER CYCLE

LAKES (Group 02H)

72-73:02H-001
NITROGEN TRANSFORMATIONS IN SEDIMENTS AS AFFECTED BY CHEMICAL AMENDMENTS,
Chen, R.L., and Keeney, D.R.
Wisconsin University, Department of Soil Science, Madison.
Water Resources Bulletin, Vol 9, No 6, p 1136-1144, December 1973. 8 tab, 27 ref.

Descriptors: *Sediments, *Nitrogen cycle, Marl, Line, Nitrification, Denitrification, Nitrogen fixation, Methane, Methane bacteria.
Identifiers: Acid sediments, Aluminum sulfate.

A study was conducted to elucidate some of the chemical factors affecting the rate and pathways of N transformations in lake sediments. Emphasis placed on modifying a noncalcareous sediment with $CaCO_3$ to approximate the composition of a calcareous sediment. The effects of Ca^{2+}, CO_3^{2-}, Mg^{2+} and OH^- were evaluated by using appropriate chemicals. The effect of aluminum sulfate was evaluated with both sediment types. Sediment pH at 7 days was not affected by $CaCO_3$, but was decreased by aluminum sulfate. The $CaCO_3$ treatment increased the rate of ammonification, nitrification, reduction of acetylene to ethylene and methane formation, while with few exceptions the other treatments decreased the rate of the transformations studied. Aluminum sulfate, which has been proposed as a lake restoration treatment, increased ammonification but decreased most of the other transformations.

Section IX

WATER CYCLE

WATER IN PLANTS (Group 02I)

72-73:02I-001
WATER-YIELD RELATIONS FOR NONFORAGE CROPS,
Downey, L. A.
New South Wales Department of Agriculture, Leeton, Australia.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR1, p 107-115, March, 1972. 3 fig, 13 ref.
(See 72-73:02G-047)

72-73:02I-002
A SYSTEMATIC APPROACH TO SIMULATING CORN PRODUCTION SYSTEMS,
Holtman, J. B., Pickett, L. K., Armstrong, D. L., and Connor, L. J.
Michigan State University, Agricultural Engineering Department, East Lansing.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 1, p 19-23, January-February, 1973. 10 fig, 3 tab, 18 ref.

Descriptors: *Computer models, *Crop production, Simulation analysis, Crop response, Yield equations, Corn.

A study of the role of the producer as decision-maker revealed that certain informational tools were required for fruitful decisions. Three types of information identified as important for the producer's needs were: (a) long run system performance data for determining average expected return, (b) short run system performance data for immediate tactical decisions and (c) risk associated with various alternatives available for the decision. Simulation was found to be a suitable approach for obtaining the information required for the necessary decisions. A flexible approach to simulation model construction was selected as the best way to meet the differing needs of producers and the needs of researchers and extension specialists involved in improving decision-making techniques. Flexibility of application was obtained by systematic construction of component models which can be used in combinations appropriate to the decision problem. Simulation of the harvesting phase of a 200 acre corn farm was provided as one example of combining component models to provide information contributing to a particular decision.

72-73:02I-003
WATER RELATIONS OF WHEAT AS AFFECTED BY IRRIGATION AND NITROGEN FERTILIZATION,
Dougherty, C. T.
Lincoln College, Department of Plant Science, Canterbury, New Zealand.
New Zealand Journal of Agricultural Research, Vol. 16, No. 1, p 12-18, February, 1973. 6 tab, 24 ref.

Descriptors: *Soil moisture, *Crop response, *Wheat, Nitrogen, Fertilization, Fertility, Crop production, Soil-water-plant relationships.

Water potentials of flag leaves and ears on the same tiller of Kopara wheat were measured soon after ear emergence by a pressure-bomb technique. Water potentials of ears were nearly 0.5 bar higher than those of flag leaves. At soil water levels of 20%, water potentials of -8 to -9 bars were recorded at 0900 hour on a day of high solar radiation with relatively little advective heat transfer. In non-irrigated wheat, soil water levels were well below the permanent wilting point, and the water potentials of the ears were lower than -20 bars. Nitrogen fertilizer had no direct effect on ear water potential, but in non-irrigated wheat it depleted soil water, probably by increasing leaf area index and transpiration. As a result soil water levels in non-fertilized, non-irrigated plots were well above the wilting point, and the water potentials of the ear of wheat growing in them were similar to those which were irrigated.

72-73:02I-004
COMPUTER SIMULATION OF CROP PRODUCTION - POTENTIAL AND HAZARDS,
Bowen, H. D., Colwick, R. F., and Batchelder, D. G.
North Carolina State University, Agricultural Engineering Department, Raleigh.
Agricultural Engineering, Vol. 54, No. 10, p 42-45, October, 1973. 2 fig, 20 ref.

Descriptors: *Computer models, *Plant growth, Cotton, Yield equations, Crop production, Plant populations.

A summary of the work completed by various investigators in the field of computer simulation are reviewed. The purpose and progress of Project S-69 is presented. This work consists of a committee from cotton producing states in the Southwest, studying the computer simulation of the growth of cotton plants. Hazards inherent to this type of work are discussed.

72-73:02I-005
SENSITIVITY OF SOUTHERN PEAS TO PLANT WATER DEFICIT AT THREE GROWTH STAGES,
Hiler, E. A., van Bavel, C. H. M., Hossain, M. M., and Jordan, W. R.
Texas A & M University, Department of Agricultural Engineering, College Station.
Agronomy Journal, Vol. 64, No. 1, p 60-64, January-February, 1972. 8 fig, 2 tab, 12 ref.

Descriptors: *Moisture stress, *Peas, *Soil moisture, Water utilization, Efficiencies, Leaves.

Response of southern peas to different levels of water deficit at three different stages of growth was measured in a greenhouse. In each stage, plants were stressed to three levels of leaf water potential: -14 bars, -21 bars, and -28 bars. Crop susceptibility factors were determined for each stage of growth and level of plant water deficit. The flowering period was found to be the most sensitive stage, regardless of deficit level. The pod development stage was found to be least sensitive to level of deficit. A water deficit of -28 bars, however, caused a yield reduction of greater than 50% for all growth stages. Stress-day index values were calculated and related to crop yield. The use of the stress-day index concept in irrigation scheduling is discussed.

72-73:02I-006
DETERMINATION OF TOTAL NITROGEN IN PLANT MATERIAL,
Nelson, D. W., and Sommers, L. E.
Purdue University, Agronomy Department, Lafayette, Indiana.
Agronomy Journal, Vol. 65, No. 1, p 109-112, January-February, 1973. 6 tab, 21 ref.

Descriptors: *Nitrogen, Nitrates, Digestion, Fertility, Crop response.

A simple and precise procedure for estimating total N in plant tissue is described; a modification is also described for analysis of samples containing high nitrate concentrations. Plant tissue samples are placed in pyrex Folin-Wu tubes and digested with a salt-catalyst-sulfuric acid mixture by heating the tubes in an aluminum block. Samples are digested at the boiling point of the mixture for 60 min. after initial clearing of the digests. Analyses of diverse plant materials, containing from 0.006 to 0.3% Nitrate-N, indicated that the proposed and standard AOAC procedures yielded essentially the same total N values. The coefficient of variation for the proposed methods varied from 0.87 to 1.10%. The tube digestion procedures described allows digestion of 60 plant samples simultaneously and thus greatly improve the efficiency of total N determinations.

72-73:02I-007
A MODEL FOR ESTIMATING DESIRED LEVELS OF NITRATE-N CONCENTRATION IN COTTON PETIOLES,
Grimes, D. W., Dickens, W. L., Yamada, H., and Miller, R. J.
California University, Department of Water Science and Engineering, Davis.
Agronomy Journal, Vol. 65, No. 1, p 37-41, January-February, 1973. 5 fig, 3 tab, 14 ref.

Descriptors: *Nitrogen, *Fertilizers, *Cotton, Crop response, Water management (applied), Water pollution sources.

Field studies were conducted on two widely different soils over a three-year period in a semiarid irrigated region to establish functional relations between responses of cotton plants and the major production input factors: water, nitrogen, and plant density. The nitrate-nitrogen concentrations of petioles from the most recently matured leaves were influenced by N-fertilization level, time of sampling in the season, and water management. Plant population did not alter the nitrate-N levels of petioles. High concentrations were associated with large amounts of N applied in side-dress soil applications. On a fine-textured soil with a high water-retention capacity N side-dressed after emergence was not taken up by the plant until the first irrigation was added. Concentrations of nitrate-N in petioles at critical times in the season were characterized by a 2nd-degree polynomial model having water and nitrogen quantities as independent variables.

72-73:02I-008
INTERNAL LEAF WATER STATUS AND TRANSPORT OF WATER IN RICE PLANTS,
Tomar, V. S., and Ghildyal, B. P.
G. B. Pant University of Agriculture and Technology, Department of Soil Science, Pantnagar, Nainital, India.
Agronomy Journal, Vol. 65, No. 6, p 861-865, November-December, 1973. 8 fig, 26 ref.

Descriptors: *Rice, *Water utilization, *Transpiration, Water transfer, Leaves, Crop response, Crop production.

The objective of this study was to relate transpiration rate and leaf water potential to relative water content. This information may be useful in predicting the effect of soil moisture stress on growth and yield. Rice variety 'IR-8' was grown in the greenhouse for 50 to 60 days under submergence and -1/3 bar soil matric potential, and then allowed to wilt. The pressure potential of leaves approached zero at a total water potential of about -19.5 bars, corresponding to 0.33 relative water content. Leaves experienced a change in cell elasticity at about 3 bars pressure potential and -10 bars total water potential. Transpiration rate decreased with leaf water potential, but it was independent of depletion of soil moisture content above 0.21 and 0.18 for plants grown in submerged and unsaturated soil conditions, respectively. These moisture contents correspond to -0.8 bar and -2.0 bars matric potential.

72-73:02I-009
ROOTING DENSITY AND WATER EXTRACTION PATTERNS FOR CORN,
Taylor, H. M., and Klepper, B.
United States Department of Agriculture, Agricultural Research Service, Ames, Iowa.
Agronomy Journal, Vol. 65, No. 6, p 965-968, November-December, 1973. 3 fig, 4 tab, 12 ref.

Descriptors: *Hydraulic conductivity, Water utilization, Plant growth, Consumptive use, Root distribution, Root systems, Corn.

An experiment was conducted to compare water-absorbing efficiency, per centimeter of root, of corn roots deep in the profile with that of roots near the soil surface. Plants were grown in a rhizotron compartment with rainfall excluded by a metal cover over the soil. Soil water content was determined with a neutron probe; rooting density, from measurements of roots on the glass viewing surface of the compartment. Leaf area was calculated by a length-width method and plant height was measured daily. For the first weeks, transpiration exceeded pan evaporation, but toward the end of the experiment it was about half as much as pan evaporation. Water uptake per centimeter of root was affected most by soil hydraulic conductivity, and at a given conductivity, it was greater at lower root densities. For the conditions of these experiments, roots deep in the profile were probably more effective per centimeter of root for water uptake than shallow roots because they were younger and were in wetter soil.

72-73:02I-010
EFFECT OF ESTABLISHMENT METHOD, VARIETY, AND SEEDING RATE ON THE PRODUCTION AND QUALITY OF ALFALFA UNDER DRYLAND AND IRRIGATION,
Hansen, L. H., and Krueger, C. R.
South Dakota State University, Plant Science Department, Brookings, South Dakota.
Agronomy Journal, Vol. 65, No. 5, p 755-759, September-October, 1973. 1 fig, 3 tab, 10 ref.

Descriptors: *Alfalfa, Planting management, Crop response, Management.

This study was designed to compare alternative establishment methods and determine the influence of alfalfa varieties and seeding rates on dry matter and crude protein production and herbage quality. The relationship between alfalfa plant density and root+crown weight and their effect on forage yield were evaluated. Pure stands of alfalfa were established by four methods: (1) no herbicide or companion crop (check); (2) a pre-plant herbicide, S-ethyl dipropylthiocarbamate (EPTC); (3) a companion crop of oats harvested for grain. Three alfalfa varieties were evaluated: T3X-8 hybrid, 'Saranac,' and 'Vernal.' Four alfalfa seeding rates were compared: 4.5, 9.0, 13.5, and 17.9 kg/ha of pure-live-seed. Studies were conducted at three locations in South Dakota. Experiments at Gayville and Norbeck were under dryland conditions and at

Brookings under irrigation.

72-73:02I-011
EFFECT OF ANTITRANSPIRANTS ON YIELD OF GRAIN SORGHUM UNDER LIMITED IRRIGATION,
Fuehring, H. D.
New Mexico State University, Agricultural Experiment Station, Clovis.
Agronomy Journal, Vol. 65, No. 3, p 348-351, May-June, 1973. 5 fig, 15 ref.

Descriptors: *Evapotranspiration, *Control, *Grain sorghum, Crop response, Yield.

Reduction of the degree and length of periods of moisture stress through the use of antitranspirants to control stomatal opening may increase the amount of time when photosynthesis takes place thus increasing crop yield with the water available. The purpose of this study was to determine the proper material, method, and timing of application for field use. Under limited irrigation conditions in the field, grain sorghum was sprayed at various times and rates with phenylmercuric acetate (PMA), atrazine, and Folicote. Mean grain yield increases of 5 to 17% were obtained, indicating considerable economic possibility. Rates of application required were approximately 60 g/ha for PMA, 130 g/ha for atrazine, and 2 liters/ha for Folicote. However, more work is needed on rates and volume of spray. Application just prior to the boot stage was more effective than a later application.

72-73:02I-012
ESTIMATING TRANSPIRATION RESISTANCE,
Brun, L. J., Kanemasu, E. T., and Powers, W. L.
Kansas State University, Department of Agronomy, Manhattan.
Agronomy Journal, Vol. 65, No. 2, p 326-328, March-April, 1973. 2 fig, 3 tab, 5 ref.

Descriptors: *Transpiration, *Evapotranspiration, *Water utilization, Stomata, Plant growth, Plant physiology, Plant tissues, Computer models, Lysimeters.

Transpiration resistance was determined in a sorghum canopy by two methods based on the stomatal resistance of all the leaves on a plant and a third method based on the stomatal resistance of only the upper three leaves. Stomatal resistance was measured with the diffusion porometer. The three methods of determining transpiration resistance included: (i) harmonically averaging the stomatal resistance of all the leaves on a plant; (ii) dividing the crop canopy into layers and weighing each layer resistance by its leaf area index; and (iii) harmonically averaging the stomatal resistances of the upper three leaves of the plant. Methods 1 and 2 gave almost identical estimates of transpiration resistance. When methods 1 and 3 were evaluated by the Monteith evapotranspiration model, the evapotranspiration estimate using method 1 gave closer agreement with lysimeter evapotranspiration than when method 3 was used in the model.

72-73:02I-013
WATER-USE EFFICIENCY AND ITS RELATION TO CROP CANOPY AREA, STOMATAL REGULATION, AND ROOT DISTRIBUTION,
Teare, I. D., Kanemasu, E. T., Powers, W. L., and Jacobs, H. S.
Kansas State University, Evapotranspiration Laboratory, Manhattan.

Agronomy Journal, Vol. 65, No. 2, p 207-211, March-April, 1973. 8 fig, 1 tab, 17 ref.

Descriptors: *Evapotranspiration, *Water utilization, Sorghum, Soybeans, Root development, Lysimeters, Leaves.

The differences in water-use efficiency between sorghum and soybean were compared in terms of leaf area index (LAI), size of root system, canopy stomatal resistance (RC), net assimilation rate (NAR), and evapotranspiration (ET). The field water budget was measured by recording the rainfall and irrigation water applied in relation to the ET as measured with two weighing lysimeters. The evapotranspiration rates of the two crops began to diverge about August 15. This was the period when the soybean canopy began to close and the soybean LAI increased to about 1.5 times that of sorghum. NAR for sorghum during stalk elongation and heading (Aug. 15) was nearly four times that of soybeans during that time. Water-use efficiency of sorghum was approximately three times that of soybeans on dry matter or grain yield bases.

72-73:02I-014

ON THE PRESSURE CHAMBER TECHNIQUE FOR ESTIMATING LEAF WATER POTENTIAL IN SORGHUM,

Blum, A., Sullivan, C. Y., and Eastin, J. D.
The Volcani Center, Department of Agronomy, Bet Dagan, Israel.
Agronomy Journal, Vol. 65, No. 2, p 337-338, March-April, 1973. 2 fig, 7 ref.

Descriptors: *Xylem, *Pressure, Pressure measuring instruments, Sorghum.

A leaf sample holder, constructed from Silicon rubber and accomodated into a brass flange, reduced leaf crushing under pressure. It was found that pressure chamber readings cannot be directly used as an estimate of leaf water potential, but should be corrected according to a calibration against a thermocouple psychrometer determinations of leaf water potential. Different rates of pressure increase in the chamber affected the regression between xylem pressure and leaf water potential. The regression improved with a greater pressure rate increase as indicated by smaller error variance estimate. No differences were detected between genotypes in this regression. This technique is, therefore, useful if worked out according to a calibration curve at a standard rate of pressure increase.

72-73:02I-015

MEASUREMENT OF LEAF WATER POTENTIAL IN WHEAT WITH A PRESSURE CHAMBER,

Frank, A. B., and Harris, D. G.
United States Department of Agriculture, Northern Great Plains Research Center, Mandan, North Dakota.
Agronomy Journal, Vol. 65, No. 2, p 334-335, March-April, 1973. 1 fig, 7 ref.

Descriptors: *Pressure, *Plant tissues, *Moisture, Xylem, Pressure measuring instruments, Wheat.

Estimates of leaf water potential obtained with a pressure chamber and with thermocouple psychrometers were compared for wheat leaves at late tillering and early heading stages of growth. The methods were linearly related for both stages of growth, but the equations were different. The pressure chamber required a separate calibration for estimating water potential of leaves from two locations on wheat plants.

72-73:02I-016
PORTABLE REFLECTANCE METER FOR ESTIMATING CHLOROPHYLL CONCENTRATIONS IN LEAVES,
Wallihan, E. F.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Agronomy Journal, Vol. 65, No. 4, p 659-662, July-August, 1973. 4 fig, 2 tab, 7 ref.

Descriptors: *Chlorophyll, Measurement, Leaves, Citrus fruits.

The need to measure changes of chlorophyll concentration in citrus leaves required a nondestructive method of analysis applicable to field use. Light reflectance in the wavelength region of 600 nm had been shown to be useful for this purpose but existing reflectance meters were too bulky for field use and generally required line power. The instrument described here is battery operated, compact, and measures light reflectance in a band of wavelengths from 610 nm to 700 nm from four miniature incandescent lamps. Arrangement of the light unit on a spring clamp permits readings in the field on several leaves per minute. Calibration against measured chlorophyll concentrations yields a log curve revealing maximum sensitivity at low chlorophyll concentrations. Tests on leaves from iron-deficient orange trees showed the coefficient of variability to be in the vicinity of ±15%. By reading 20 replicate leaves, sampling errors were compensated sufficiently to give precision of about ±3%.

72-73:02I-017
REFLECTANCE, TRANSMITTANCE, AND ABSORPTANCE OF LIGHT BY SUBCELLULAR PARTICLES OF SPINACH LEAVES,
Gausman, H. W.
United States Department of Agriculture, Agricultural Research Service, Weslaco, Texas.
Agronomy Journal, Vol. 65, No. 4, p 551-553, July-August, 1973. 2 fig, 16 ref.

Descriptors: *Photosynthesis, Reflectance, Chlorophyll, Energy conversion, Plant physiology.

Subcellular particles of spinach leaves were differentially sedimented and resuspended in a buffered sucrose solution. A spectroreflectometer was used to measure R and transmittance (T) over the 500- to 2,500-nm wavelength interval (WLI) on replicated aliquots of five preparations: buffered sucrose solution; chloroplast preparation; S1, sediment of chloroplast preparation supernatant; S2, sediment of S1 supernatant; and S3, sediment of S2 supernatant. All suspensions of particulates caused less R than the buffered sucrose solution over the 500- to 650-nm WLI. The chloroplast preparation, compared with the buffered sucrose solution, increased R over the 750- to 950-nm WLI. The chloroplast preparation, compared with the buffered sucrose solution, S2, and S3, decreased T over the 500- to 1,250-nm WLI; S1 decreased T over the 500- to 900-nm WLI. A conclusion was reached that subcellular particles in leaves contribute to the R and A of IR light.

72-73:02I-018
A COMPUTER SIMULATION OF CORN GRAIN PRODUCTION,
Baker, C. H., and Horrocks, R. D.
Missouri University, Agronomy Department, Columbia.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 6, p 1027-1029, 1031, November-December, 1973. 3 tab, 22 ref.

Descriptors: *Computer models, *Mathematical models, *Plant growth, Corn, Crop response.

When the ideal simulation model is pictured, it is evident that the trend of crop research needs to be changed. Instead of researching a plant on a monthly or seasonal basis, it should be considered on a daily basis. The corn plant, like most biological systems, is a highly variable and highly buffered system. A system of this complexity does not respond to average or monthly weather - instead it is affected each day by that day's weather. The effect of similar weather on two successive days also differs to a degree since the plant has changed. In a month's time, the plant can change many times. Development of a simulation model is not limited by computer capacity, but rather is limited by lack of mathematical definitions for the basic plant processes.

72-73:02I-019
PLANT WATER STATUS IN RELATION TO CLOUDS,
Stansell, J. R., Klepper, B., Browning, V. D., and Taylor, H. M.
Georgia University, Coastal Plain Experiment Station, Tifton.
Agronomy Journal, Vol. 65, No. 4, p 677-678, July-August, 1973. 2 fig, 2 ref.

Descriptors: *Evapotranspiration, *Soil moisture, Plant tissues, Cloud cover, Clouds.

Clouds can cause significant changes in plant water status in a short time. Therefore, care should be taken to sample different treatments under comparable radiation.

72-73:02I-020
CONSIDERING IRRIGATED GRASS? TAKE A TIP FROM NEW MEXICO,
Irrigation Age, Vol. 6, No. 10, p 18-19, 32, 34, 35, May, 1972. 2 fig.

Descriptors: *Grasses, *Range grasses, Wheatgrasses, Switchgrass, Plant groupings, Hay, Pastures, Ranges, Irrigation.

They are row cropping irrigated grass in Curry County, New Mexico, and making the crop pay handsome dividends when the net return is compared to irrigated wheat and milo. Farmers in the area are literally farming the grass. Several farmers in and around Clovis have the records to show $70, $80 and more net profit per acre from irrigated grass. An extensive economic study revealed a net of $7.81 per acre for irrigated wheat and $16.21 per acre for irrigated milo. Most popular grasses to date in the area are Jose Tall Wheatgrass for the cool season pasture and Blackwell Switch Grass for the warm season species.

Section X

WATER CYCLE

EROSION AND SEDIMENTATION (Group 02J)

72-73:02J-001
SEASONAL SEDIMENT YIELD PATTERNS OF U.S. RIVERS,
Wilson, L.
Environment Consultants, Inc. New York.
Water Resources Research, Vol 8, No 6, p 1470-1479, December 1972. 5 fig, 1 tab, 19 ref.

Descriptors: *Sediment yield, United States, *Seasonal, *Climatology, Erosion, Rainfall, Runoff, Water yield, Land use, Sediment discharge, Data collections, *Rivers.
Identifiers: *Sedihydrograms.

The sedihydrogram is a double log plot of mean monthly sediment yield against mean monthly water yield. Sediment regimes seen on the sedihydrogram are explained by a model that relates basin hydrology to the dominance of common air masses. Mediterranean and continental climate and erosion regimes are well expressed in U.S. rivers. Mediterranean regimes in the western United States have a dry summer and a wet winter with strong seasonal contrasts between early wet season floods and less turbid flow events later in the wet season. Large sediment yield values may be expected from basins in which seasonal desiccation alternates with heavy rains. Continental regimes in the central and eastern United States have a water yield event in late winter or early spring with a low sediment concentration. Summer storms produce high concentrations and a low water yield. The summer component of the sedihydrogram is dominant in dry regions but minor in humid areas, where vegetation offers effective protection from storms. Basins in eastern humid states have a sedihydrogram typical of arid regions if strip mining or urbanization has had an important effect on the basin hydrology. Most climate regimes show a seasonal shift in the parameters of the sediment transport curve, so that an analysis of seasonally grouped data results in improved equations for relating sediment movement to environmental controls. The prediction of sediment yield requires that separate consideration be given to those factors affecting runoff and those affecting sediment concentration.

72-73:02J-002
RUNOFF, EROSION, AND SOLUTES IN THE LOWER TRUCKEE RIVER, NEVADA, DURING 1969,
Glarcy, P.A., Van Denburgh, A.S., and Born, S.M.
Geological Survey, Carson City, Nevada
Water Resources Bulletin, Vol 8, No 6, p 1157-1172, December 1972. 8 fig, 5 tab, 15 ref.

Descriptors: *Water yield, *Sediment yield, *Dissolved solids, *Nevada, Erosion, Runoff, Water chemistry, Hydrogeology, Data collections, Water balance, Sediment transport.
Identifiers: *Truckee River (Nevada).

The Truckee River heads in the Sierra Nevada at Lake Tahoe, and terminates in Pyramid Lake. During the 1969 water year, flow about 9 miles upstream from the mouth (974,000 acre-ft) was almost four times the long-term average, due mainly to heavy winter rains and spring snowmelt. A short period of low-altitude rainfall produced the highest concentrations of suspended sediment, whereas a much longer subsequent period of snowmelt yielded a much greater total quantity of material. The upper 90% of the basin yielded about 630,000 tons of sediment at the Nixon gage, whereas an estimated 6.8 million tons was contributed by erosion of about 200 acres of river bank below the gage. Solute content at the gage ranged from 80 to 450 mg/liter, dominated by calcium, sodium, and bicarbonate, plus silica in the most dilute snowmelt and chloride in the most concentrated low flows. Solute load totaled about 130,000 tons, of which the principal constituents in Pyramid Lake-sodium plus equivalent bicarbonate and chloride-amounted to almost 40,000 tons. The total solute load during a year of average flow may be 45,000-55,000 tons, including 18,000-22,000 tons pf principal lake constituents.

72-73:02J-003
PHYSICO-CHEMICAL FACTORS IN EROSION OF COHESIVE SOILS,
Sargunam, A., Riley, P., Arulanandan, K. and Krone, R.B.
California University, Davis, Department of Civil Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers,
Vol 99, No HY3, p 555-558, March 1973. 2 fig, 1 tab, 6 ref.

Descriptors: *Soil erosion, *Saline soils, *Cohesive soils, *Ion exchange, *Leaching, Pore water, Soil chemistry, Calcium, Sodium, Magnesium,Chlorides.

Critical hydraulic shear stress, defined as that stress which must be exceeded to cause erosion of a soil, is related to mechanical properties of the soil. Susceptibility of a cohesive soil to erosion also depends on the pore fluid composition. Cylindrical specimens were prepared by consolidation from slurries in which the pore fluid had been altered by the addition of Na, or Mg, or Ca chlorides. Using sodium salt, the critical shear stress increased markedly with increasing concentration even through the SAR was also increasing. The change in erosion rate for the calcium soil, however, is about one-twentieth that of the sodium soils. This probably results from the stronger interparticle bonds and the lesser hydration associated with absorbed calcium ions. The higher the interior pore concentration or the lower its SAR the greater will be the cohesion when the pore space around surface particles swells to a new near-equilibrium volume. Increasing the concentration or reducing the SAR of eroding fluid will also increase the equilibrium cohesion of surface particles and limit surface particle swell.

72-73:02J-004
FIELD CALIBRATION AND EVALUATION OF A NUCLEAR SEDIMENT GAGE,
Welch, N.H., and Allen, P.B.
Agricultural Research Service, Chickasha, Oklahoma. Southern Great Plains Watershed Research Center.
Water Resources Research, Vol 9, No 1, p 154-158, February 1973. 3 fig, 2 tab, 8 ref.

Descriptors: *Suspended load, *Sediment load, *Gaging, *Gages,*Nuclear meters, Sampling, Calibrations, Instrumentation.
Identifiers: *Nuclear sediment gages.

Nuclear sediment gage readings were compared to stream cross-sectional sediment concentrations for several storm events over a 3-year period. Calibration curves, developed by least-squares analysis, are presented for individual and combined storm events. Correlation coefficients for individual or combined storm events ranged from minus 0.86 to minus 0.99, and all were significant at the 1% level. Standard errors of estimate ranged from plus minus 172 to plus minus 1884 ppm. Sediment concentrations predicted with the calibration curves developed in this study were accurate enough for most applications. Although the particular nuclear gage used is probably unsatisfactory for general use, the principle of monitoring sediment concentrations by nuclear techniques appears sound and feasible.

72-73:02J-005
SEDIMENT YIELD COMPUTED WITH UNIVERSAL EQUATION,
Williams, J.R., and Berndt, H.D.
Agricultural Research Service, Riesel Texas. Soil and Water Research Division.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 98, No HY12, Paper 9426, p 2087-2098, December 1972. 3 fig, 3 tab, 8 ref, append.

Descriptors: *Sediment yield, *Soil erosion, *Mathematical models, Equations, Sedimentation, Grassed waterways, Erosion control, Reservoir silting, Sediment discharge, Vegetation effects, Watershed management.

Sediment yield from watersheds may be predicted by modifying the Universal Soil Loss Equation and using a delivery ratio. All factors of the equation except the rainfall factor were modified to increase computational efficiency. In addition, the erosion-control practice factor was expanded to include the separate effect of grassed waterways. Delivery ratios were computed for five small blackland watersheds and related to watershed characteristics. Ste-wise multiple regression was used to develop equations for predicting delivery ratios. The regression analysis showed that slope of the main stem channel explains about 99% of the variation. The modified Universal Soil Loss Equation and the equation for predicting delivery ratios form a sediment yield model that should be useful in reservoir design and water quality studies.

72-73:02J-006
PREDICTING SEDIMENT YIELD IN WESTERN UNITED STATES,
Flaxman, E.M.
Soil Conservation Service, Portland, Oregon. Engineering and Watershed Planning Unit.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol 98, No HY12, Paper 9432, p 2073-2085, December 1972. 1 fig, 2 tab, 5 ref.

Descriptors: *Sediment yield, *Erosion, *Equations, *Sheet erosion, Statistics, Statistical methods, Regression analysis, Sedimentation, Land use, Climates, Soil erosion, Vegetation effects, Soil physical properties.
Identifiers: Western U.S.

An equation for predicting the average annual sediment yield from sheet erosion was developed through multiple-regression analysis. Most of the variation in yield is explained with data obtained by measurement of four watershed characteristics. A climatic factor as indirect expression of vegetative cover), the average watershed slope, and two soil factors are the variables used. A good correlation of computed with measured sediment yields is obtained except at the lower rates of sedimentation. Improvements in predictive values can be achieved with experience in judging the necessary adjustments in the vegetative cover factor, through soil sampling, and by use of longtime sediment yields. The data selected for this analysis exclude the influence of extensive gully or stream bank erosion

72-73:02J-007
CHAPTER V: SEDIMENT CONTROL METHODS: C. CONTROL OF SEDIMENT IN CANALS,
American Society of Civil Engineers, New York. Task Committee for Preparation of the Sedimentation Manual.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol 98, No HY9, p 1647-1689, September 1972. 20 fig, 1 tab, 37 ref, append.

Descriptors: *Canals, *Desilting, *Sediment control, Bed load, Channels, Diversion structures, Hydraulic models, Hydraulics, Scour, Sedimentation, Settling basins, Sluices, Streamflow, *Suspended sediments, Streams, Velocity, Dredging, Sediments, Sediment transport, Canal design.
Identifiers: Sediment excluders, Diversion works, Ejectors, Headworks.

Sediment transported by natural streamflow has often presented major problems to the canal designer. To prevent clogging and costly maintenance operations, sediment must be removed from the water at the canal intake or transported through the canal system with a minimum of accumulation within the canal prism and structures. Complete elimination of the sediment at the diversion point generally is impractical and too costly in most cases. However, a combination of sediment control at the headworks and design of canal hydraulics to minimize deposition through the canal length can be used to provide practical solutions to the problem. Some factors to be considered in canal design are: (1) amount and type of sediment to be removed or carried into the canal system, (2) type of earth materials through which the canal is to be constructed, and (3) type of lining, when used. Structures that reduce the amount of bedload entering canals are diverters or ejectors; to remove suspended small particles, some type of settling basin placed in the canal just downstream from the headworks is used. Several structures are shown and discussed.

72-73:02J-008

SOIL AND WATER LOSSES AS AFFECTED BY TILLAGE PRACTICES,
Onstad, C.A.
United States Department of Agriculture, Agricultural Research Service, Soil and Water Conservation, Brookings, South Dakota.
Transaction of the American Society of Agricultural Engineers, Vol 15, No 2, p 287-289, March-April, 1972. 1 fig, 6 tab, 8 ref.

Descriptors: *Soil conservation, *Water conservation, *Erosion control, Soil erosion, Agricultural runoff, Cultivation, Mulching, Sediment control.

Four corn tillage treatments were compared with respect to their effect on soil and water losses in a 6-year study. The treatments tested were: conventional tillage, mulch tillage, till-planted up and down slope, and till-planted on the contour. Higher runoff on the conventionally tilled plots and lower runoff on the contoured till-plant tteatment were significant at the 1-percent level. Runoff differences were not significant for the mulch-tilled and the till-planted up and down slope. The differences in soil loss were also significant in the same manner as runoff. These measurements were made on slope lengths of 72.6 ft. Longer slopes would have more soil loss per unit area. Extrapolated to a 300-foot slope length, the soil loss from the conventional treatment would have exceeded 5 tons per acre even though growing season rainfall was only 80 percent of normal.

72-73:02J-009

PREDICTION OF RUNOFF AND EROSION FROM NATURAL RAINFALL USING A RAINFALL SIMULATOR,
Young, R.A., and Burwell, R.E.
Agricultural Research Service, Morris, Minnesota. North Central Soil Conservation Research Center.
Soil Science Society of America Proceedings, Vol 36, No 5, p 827-830, September-October 1972. 3 fig, 4 tab, 6 ref.

Descriptors: *Erosion, *Rainfall-runoff relationships, *Simulated rainfall, *Rainfall simulators, Artificial precipitation, Model studies, On-site tests, Soil erosion, Runoff.

To interpret and apply the results of studies of runoff and erosion using simulated rainfall, it is necessary to know the relative effects of natural vs. simulated rainfall. A comparison was made of the soil and water losses from three natural storms and three simulated storms on cultivated fallow plots under similar rainfall and soil conditions. Soil losses from the three simulated storms averaged 77% of those from the natural rainstorms, with an average erosion index value for the simulated storms of 78% of that for natural rainstorms. The runoff from the simulated storms compared quite closely to runoff from the natural storms.

72-73:02J-010

WATER-SEDIMENT SPLITTER FOR RUNOFF SAMPLES CONTAINING COARSE-GRAINED SEDIMENT,
Fleming, W.G., and Leonard, R.A.
United States Department of Agriculture, Watkinsville, Georgia.
Soil Science Society of America Proceedings, Vol 37, No 6, p 961-962, November-December 1973. 2 fig, 1 tab,

Descriptors: *Suspension, *Suspended solids, *Sampling, Sediment sorting, Sediment yield, Runoff, Erosion.

A water-sediment sample splitter was designed and constructed for dividing samples up to 20 liters into three equal and representative smaller samples for chemical and physical analyses. This funnel-shaped device with a mechanical agitator divides samples containing particles up to 2 mm without first separating the sediment from the water. Evaluation showed that the splitter divided samples containing coarse sediments into three parts with a distribution of 33% ± 2% in each. The device has application in assuring representative samples of runoff from water shed or similar runoff studies.

72-73:02J-011
DISPERSION OF CONTAMINATED SEDIMENT BED LOAD,
Shen, H.W. and Cheong, H.F.
Colorado State University, Department of Civil Engineering, Fort Collins.
Journal of the Hydraulics Division, American Society of Civil Engineers,
Vol 99, No HY11, p 1947-1965, November 1973. 15 fig, 2 tab, 6 ref.

Descriptors: *Bed load, *Dispersion, *Erosion, Sedimentation, Hydraulics, Water pollution sources, Radioactivity, Sediment transport.

Dispersion of instantaneously released contaminated bed sediments in analyzed within the framework of a Lagrangian probabilistic model. The time and space concenctarion distributions, with the parameters computed on the basis of the same rate of mass movement and a constant rate of spread, approach Gaussian form asymptotically. A procedure is suggested for deriving approximations to the envelopes of the distribution curves parameterized by either the time or distance. The method is also applicable when the shape factor of the particle step length distribution takes on nonintegral values greater than one. Where the formality approximation is satisfactory, the critical duration for a given degree of pollution varies in direct proportion to the square root of the distance from the source. Graphical results for the critical time limits for the absorption of radiation from contaminated particles for different positions of the subject are also presented.

72-73:02J-012
EFFICIENT UTILIZATION OF WATER THROUGH LAND MANAGEMENT,
Cormack, J.M.
Rhodesia Department of Conservation and Extension.
Rhodesia Agricultural Journal, Vol 69, No 1, p 11-16, January-February, 1972.
6 fig.

Descriptors: *Erosion, *Water quality, Soil conservation, Water conservation, Sedimentation, Land management.

The problem of erosion in Rhodesia is explained. Possible solutions and government programs are outlined.

72-73:02J-013
EFFECT OF CORN STOVER ON PHOSPHORUS IN RUN-OFF FROM NONTILLED SOIL,
Ketcheson, J.W. and Onderdonk, J.J.
Guelph University, Department of Land Resource Science, Guelph, Canada.
Agronomy Journal, Vol 65, No 1, p 69-71, January-February 1973. 4 tab, 6 ref.

Descriptors: *Nutrient removal, *Phosphorus, *Runoff, Erosion, Mulching, Corn, Soil conservation, Water pollution sources.

The effect of stover on soil and phosphorus (P) removal was determined for a well-drained till soil with 7% slope. Corn was planted without tillage after 32P-tagged P fertilizers was applied broadcast and covered with a corn stover mulch in one treatment or left bare in a second treatment. Run-off was collected and analyzed from one simulated and from two natural rainfall events. Stover reduced soil P in run-off by 65% and fertilizer P by 97%. These reductions were achieved by a decrease in total run-off and by a decrease in the concentration of suspended soil in it. Of the 29 kg of fertilizer P applied per ha, 3.85 kg and 0.13 kg were removed over all run-off events from the no stover and stover treatments, respectively. This corresponded to 8.5 and 1.3%, respectively, of the total P removal, which varied from 45 kg/ha without stoved to 10 kg/ha with stover. The liquid fraction of the run-off carried the least amounts of either soil or fertilizer P.

72-73:02J-014
CONCEPTS OF CONSERVATION TILLAGE SYSTEMS USING SURFACE MULCHES,
Wittmuss, H.D., Triplett, G.B., Jr., and Greb, B.W.
Nebraska University, Agricultural Engineering Department, Lincoln.

Presented at National Conservation Tillage Conference, March 28-30, 1973. Des Moines, Iowa. Technical Paper No 1, 14 p, 1 tab, 43 ref.

Descriptors: *Soil conservation, *Erosion, Soil erosion, Water conservation, Cultivation, Erosion control, Erosion rates.

A brief summary of the need and effects of conservation tillage is presented. Effects on soil erosion of some tillage practices are listed.

Section XI

WATER CYCLE

CHEMICAL PROCESSES (Group 02K)

72-73:02K-001
CHEMISTRY AND OCCURRENCE OF CADMIUM AND ZINC IN SURFACE WATER AND GROUNDWATER,
Hem, J.D.
Geological Survey, Menlo Park, California. Water Resources Division.
Water Resources Research, Vol 8, No 3, p 661-679, June 1972. 11 fig, 3 tab, 41 ref.

Descriptors: *Water chemistry, *Zinc, *Cadmium, Surface waters, Groundwater, Trace elements, Spectrophotometry, Water analysis, Path of pollutants, Water pollution sources, Carbonates, Solubility, Fallout.

The median concentration of zinc in 726 filtered samples of water taken from rivers and lakes of the United States in November 1971 was close to 20 migrograms per liter, and the mediam concentration of cadmium was a little below 1 microgram per liter. The concentrations of both elements tended to be consistently higher in water from northeastern and southeastern states. Chemical thermodynamic calculations summarized by solubility graphs suggest that the carbonate and hydroxide solubilities of these elements are higher than the concentrations commonly found, but for 24 to 80 analyses for which chemical equilibrium computations could be made, saturation with respect to one or both of the metals was closely approached. Zinc solubility may also be controlled by silicate in some waters. Biological factors and sorption by stream sediments may also be significant controls. Concentrations of cadmium above 10 micrograms per liter may be stable in water having low total solute concentrations and pH and can be difficult to remove by conventional water treatment processes.

72-73:02K-002
CHLORIDE BALANCE OF SOME FARMED AND FORESTED CATCHMENTS IN SOUTHWESTERN AUSTRALIA,
Peck, A.J., Hurle, D.H.
Commonwealth Scientific and Industrial Research Organization, Wembley (Australia)
Water Resources Research, Vol 9, No 3, p 648-657, June 1973. 1 fig, 5 tab, 25 ref.

Descriptors: *Saline water, *Leaching, *Salt balance, *Australia, Water quality, Water chemistry, Water balance, Chlorides, Vegetation effects, Land use, Water pollution sources, Saline soils.

Loss of chloride in streamflow from forested catchments in southwestern Australia is only slightly greater than the total annual input from rain and dust. However, salt flow from catchments in which a significant area of the forest vegetation has been cleared for farming is much larger and exceeds salt input by up to 690 kg/ha per yr, or a factor of 21. The net loss of Cl results from decreased storage in catchment soil water. Removal of the forest begetation increases groundwater discharge of catchments by amounts ranging from about 1 to 13 cm per year. Characteristic times for equilibration of Cl input and loss on farmed catchments are estimated to range from 30 to 400 years. In equilibrium the salty streams draining farmed catchments would yield water with Cl concentration acceptable for drinking.

72-73:02K-003
SIMULATION OF HYDROCHEMICAL PATTERNS IN REGIONAL GROUNDWATER FLOW,
Schwartz, F.W., and Domenico, P.A.
Alberta University, Edmonton. Department of Geology.
Water Resources Research, Vol 9, No 3, p 707-720, June 1973. 7 fig, 8 tab, 20 ref.

Descriptors: *Water chemistry, *Hydrogeology, *Simulation analysis, *Groundwater basins, Mass transfer, Equilibrium, Kinetics, *Canada, Mathematical models, Leaching, Weathering, Geochemistry.

The chemical state of a regional groundwater system in which several processes are acting is described by a simulation model that incorporates partial equilibrium, mass transfer, and reaction kinetics. Mineral dissolution, saturation constraints in dissolution, the degree of saturation, partial pressures of CO2, reaction kinetics, and the residence time of the groundwater flow play different roles in determining the spatial distribution of ionic constituents. Simultaneous evaluation of several geochemical processes permits the study of interdependent phenomena such as shifts in equilibrium concentrations resulting from the addition of common ions by cation exchange or sulfate reduction processes. The utility of the model was demonstrated by applying it to the groundwater reservoir in the Upper Kettle Creek, Ontario, Canada, where a favorable comparison was achieved between the real and the theoretical hydrochemical patterns.

72-73:02K-004
SIMULTANEOUS TRANSPORT OF CHLORIDE AND WATER DURING INFILTRATION,
Kirna, C., Nielsen, D.R., Biggar, J.W.
California University, Davis. Department of Water Science and Engineering.
Soil Science Society of America Proceedings, Vol 37, No 3, p 339-345,
May-June 1973. 7 fig, 1 tab, 27 ref.

Descriptors: *Leaching, *Diffusion, *Chlorides, *Infiltration, Mass transfer, Convection, Dispersion, Path of pollutants, Mixing, Soil water movement, Water chemistry, Tracers, Tracking techniques, Radioisotopes.
Identifiers: Chloride transport.

Displacement of chloride during infiltration was studied using soil columns for two cases: chloride initially spread on the soil surface; and chloride initially mixed with the soil. Chloride was applied as CaCl2 labeled with Cl-36. In conjunction with chloride activity measurement, gamma-ray attenuation measurement was used for monitoring the water content distribution during the simultaneous flow of chloride and water. Treatments included different levels of initial soil water content and different levels of water saturation at the soil surface during infiltration. The equations describing vertical water flow and miscible displacement of chloride were solved numerically. Experimental and calculated chloride distributions were in agreement. Chloride apparent diffusion coefficients estimated for pore water velocities less than 0.01 cm per min were nearly equal to those for molecular diffusion only. Initial soil water content did not influence the depth of chloride displacement for a given quantity of water infiltrated. Keeping the water content at the soil surface below saturation resulted in a deeper and more complete displacement of chloride.

72-73:02K-005
RELATIONSHIP BETWEEN THE CARBON ISOTOPE COMPOSITION OF SOIL CO2 AND DISSOLVED CARBONATE SPECIES IN GROUNDWATER,
Rightmire, C.T., and Hanshaw, B.B.
Geological Survey, Washington, D.C.
Water Resources Research, Vol 9, No 4, p 958-967, August 1973. 1 fig, 3 tab,
29 ref.

Descriptors: *Stable isotopes, *Carbon, *Isotope fractionation, *Water chemistry, *Hydrogeology, Groundwater, Groundwater movement, Provenance, Climatology, Tracers, Florida, Soil water, Soil gases.
Identifiers: *Carbon isotopes.

To understand the carbonate geochemistry of an aquifer system, it is helpful to determine the sources of carbon in the dissolved carbonate species. Samples of ground litter, soil organic matter, soil CO2 and groundwater were collected in the area of recharge to the principal artesian aquifer of central Florida and were analyzed for C-13 content. Analytical results yield consistent C-13/C-12 values for soil organic matter; delta C-13 (PDB) ± 23 plus or minus 1 part per thousand. The C-13/C-12 ratio of the litter samples ranges from delta C-13 (PDB) of -18.2 to -29.5 parts per thousand and indicates the presence of both Calvin and Hatch-Slack cycle plants. The C-13/C-12 of the soil CO2 ranges from -14.7 to -21.3 parts per thousand, which is consistent with the trend observed in the litter. The relationship between C-13/C-12 of the dissolved carbonate and the percent calcite saturation indicates that the C of the source CO2 is within the range expected for a humid, subtropical environment.

72-73:02K-006
HYDROCHEMICAL ENVIRONMENTS OF CARBONATE TERRAINS,
Drake, J.J., and Harmon, R.S.
McMaster University, Hamilton (Ontario). Department of Geography,
Water Resources Research, Vol 9, No 4, p 949-957, August 1973. 4 fig, 4 tab, 22 ref.

Descriptors: *Karst hydrology, *Water chemistry, Water analysis, Geochemistry, Statistics, Carbonate rocks, Hydrogeology, *Pennsylvania.

Waters within a carbonate aquifer may be classified on a hydrologic basis. To test the classification method, 166 reliable chemical analyses of carbonate waters from Pennsylvania were grouped on a hydrologic basis, and the groupings were tested by a stepwise linear discriminant function analysis. Two parameters (degree of calcite saturation and eqilibrium carbon dioxide partial pressure) are sufficient to distinguish the groups at the 0.005 confidence level and provide a reliable way to examine the geochemical evolution of the waters in the carbonate drainage basin.

72-73:02k-007
POTENTIOMETRIC TITRATION OF SULFATE IN WATER AND SOIL EXTRACTS USING A LEAD ELECTRODE,
Goertzen, J.O., and Oster, J.D.
Agricultural Research Service, Riverside, California. Salinity Lab.
Soil Science Society of America Proceedings. Vol 36, No 4, p 691-693, 1972.

Identifiers: Electrodes, Lead, *Potentionmetric titration, Soils, *Sulfates, Titration, Water pollution sources.

Sulfate concentrations in natural waters and soil water extracts were determined seimautomatically using a pb-ion electrode to indicate the solution potential change at the endpoint, a constant flow device to deliver the titrant, a pH-mV meter to measure the potential, and a strip chart recorder to plot the solution potential thus indicating the endpoint. Sulfate concentrations as low as 0.5 meq/liter in the sample solution were determined by the potentiometric titration system. This semiautomated direct titration of sulfate has the advantages of increased sensitivity and speed as compared with the precipitation method.

72-73:02K-008
DETERMINATION OF NITRATES IN SOIL EXTRACTS,
Kowalenko, C.G. and Lowe, L.E.
British Columbia University, Department of Soil Science, Vancouver, British Columbia, Canada.
Soil Science Society of America Proceedings, Vol 37, No 4, p 660, July-August, 1973. 7 ref.

Descriptors: *Water chemistry, Nitrates, Soil chemistry, Ions.

A variation of a method for nitrate analysis of water samples developed by West and Ramachandran (1966) is presented. The method can be used on soil samples in place of the phenoldisulfonic acid method with very comparable results.

72-73:02K-009
ON SOLUBILITY AND SOLUBILITY PRODUCE CONSTANTS,
Nakayama, F.S.
United States Water Conservation Laboratory, Phoenix, Arizona.
Soil Science Society of America Proceedings, Vol 37, No 4, p 661-662,
July-August, 1973.

Descriptors: *Solubility, Aqueous solutions, Chemical properties, Leaching, Saturation, Solvents.

A comment on a previously published article is voiced. A new method for determining solubility product constant is mentioned and debated but not fully presented here.

72-73:02K-010
PRESERVATION OF SOIL SAMPLES FOR INORGANIC NITROGEN ANALYSES,
Nelson, D.W., and Bremner, J.M.
Purdue University, Department of Agronomy, Lafayette, Indiana.
Agronomy Journal, Vol 64, No 2, p 196-199, March-April, 1972. 3 tab, 23 ref.

Descriptors: *Nitrates, *Inorganic compounds, *Nitrogen, Nitrogen cycle, Nitrogen fixation, Nitrogen compounds, Soil analysis.

Studies of the effects of several pretreatments and storage conditions on the inorganic N contents of 10 Iowa soils indicated that storage at -5 C in an airtight container is a satisfactory method of preserving field-moist soil samples for inorganic N analyses. Storage at this temperature did not cause a significant change in the exchangeable ammonium N, nitrate N, or fixed ammonium N contents of the soils studied. Air-drying at 22 C increased the inorganic N contents of most of the soils studied, with the average increase 4.2 ppm for exchangeable ammonium N, 1.7 ppm for nitrate N, and 4.4 ppm for fixed ammonium N. Oven-drying at 55 C resulted in a slightly larger increase in exchangeable ammonium N than did air-drying at 22 C, and drying at 22 C in ammonia-free air caused a smaller increase in exchangeable ammonium N than drying at the same temperature in laboratory air. Storage of air-dried soils in paper bags for 9 months led to marked increases in their inorganic N contents.

72-73:02K-011
IONIC ACTIVITY COEFFICIENTS IN WATER SOLUTIONS CALCULATED BY MEANS OF NOMOGRAPHS,
Zanker, A.
Kiriat-Jam "G", P.O. Box 11, Israel.
Water Research, Vol 6, No 2, p 191-195, February, 1972. 2 fig, 2 ref.

Descriptors: *Ions, Ion exchange, Solubility, Soil chemistry, Water chemistry.

A knowledge of ionic activity coefficients is a matter of importance in water research. The ionic activity coefficients in water solutions are functions of the ionic strength, the valency of the ion, and the effective ionic radius (for low ionic strengths only).

WATER SUPPLY AUGMENTATION AND CONSERVATION

SALINE WATER CONVERSION (Group 03A)

72-73:03A-001
EFFECT OF H_2SO_4 IN HIGH SODIUM IRRIGATION WATER ON THE GROWTH OF PEAS AND BEANS IN CALCAREOUS SOILS,
Ryan, J., Miyamoto, S., and Bohn, H.L.
Arizona University, Department of Soils, Water, and Engineering. Tucson.
Agronomy Journal, Vol 65, No 6, p 999-1000, November-December, 1973. 2 fig, 1 tab, 6 ref.

Descriptors: *Salinity, *Alkalinity, Sodium, Water quality, Alkaline soils, Alkaline water, Neutralization.

Preliminary experiments were conducted to evaluate the addition of H_2SO_4 to high Na water for the purpose of preventing or reducing plant uptake of Na by increasing the solubility of Ca. The addition of up to 4 meq/liter of H_2SO_4 to irrigation water containing 1 to 40 meq/liter of NaCl had no significant effect on the growth of peas and beans cropped twice in calcareous soils in greenhouse experiments. However, H_2SO_4 had an adverse effect at NaCl concentrations of 60 and 80 meq/liter. Sodium concentrations greater than 10 meq/liter appeared to decrease the yield of both plants. A leaching fraction of 0.3 ± 0.05 was maintained. The Na content of the irrigation water increased, but no reduction in Na content was observed with the H_2SO_4 treatment. The Ca content was not affectes. The results suggest that this practice was ineffective at the H_2SO_4 concentration range studied.

Section XIII

WATER SUPPLY AUGMENTATION AND CONSERVATION

WATER YIELD IMPROVEMENT (Group 03B)

72-73:03B-001
USE OF PRODUCTION FUNCTIONS TO EVALUATE MULTIPLE USE TREATMENTS ON FORESTED WATERSHEDS,
O'Connell, P.F., Brown, H.E.
Forest Service (USDA) Tucson, Arizona, Rocky Mountain Forest and Range Experiment Station.
Water Resources Research, Vol 8, No 5, p 1188-1198, October 1972. 8 fig, 2 tab, 15 ref.

Descriptors: *Water yield improvement, *Forest management, *Watershed management, *Arizona, Clear-cutting, Optimization, Economics, Water conservation, Input-output analysis, Land management, Water management (applied).
Identifiers: *Beaver Creek Watershed (Ariz.)

Alternative land treatments on Beaver Creek watersheds in northern Arizona were designed to increase water yield within a multiple use framework that includes timber, wildlife habitat, herbage, recreation, sediment, and environmental quality. Total, average, and marginal economic concepts are used to demonstrate the most efficient way to manage an area for one output. Even without price information, a range of 'best' input combinations can be identified. To determine how an area can be managed for multiple products in the most efficient way, product-product functions were developed for water, timber herbage for five strip cutting alternatives. These functions indicate the supplementary, complementary, and competetive outputs obtained from a given expenditure. To account for the dynamic nature of production in the National Forests, outputs and costs were evaluated over a 90-year period.

72-73-03B-002
CHANGES IN WATER YIELD OF SMALL WATERSHEDS BY AGRICULTURAL PRACTICES,
Richardson, C.W.
United States Department of Agriculture, Riesel, Texas.
Transactions of the American Society of Agricultural Engineers, Vol 15, No 3, p 591-593, May-June, 1972. 7 fig, 5 ref.
(See 72-73:02E-004)

Section XIV

WATER SUPPLY AUGMENTATION AND CONSERVATION

USE OF WATER OF IMPAIRED QUALITY (Group 03C)

72-73:03C-001
SOIL WATER REGIME IN ECONOMIC EVALUATION OF SALINITY IN IRRIGATION,
Bresler, E. and Yaron, D.
Volcani Institution of Agricultural Research, Bet-Dagan (Israel).
Water Resources Research, Vol 8, No 4, p 791-800, August 1972. 2 fig, 1 tab, 10 ref.

Descriptors: *Soil water, *Irrigation, *Salinity, *Irrigation efficiency, *Irrigation water, Water quality, Water quantity, Irrigation practices, Economics, Evaluation, Estimating, Computer models, Statistical models, Optimization, Systems analysis.
Identifiers: Soil water suction.

In regions with a Mediterranean climate and a semiannual alternation of rainy and irrigation seasons, it seems more efficient to control salinity by regulating the soil water regime, as an alternative to control by leaching. The soil can be leached during the rainy season by rain and/or irrigation and the total water suction can be controlled during the crop-growing irrigation season by altering the water regime. Presented is an approach for the short-run determination of the economically optimal quantity-quality combination of the irrigation water during the irrigation season, when the soil water regime and the soil salt status are changed simultaneously. A field irrigation water requirement experiment and computer and statistical models are used to estimate the functional relationships between the total water suction and the man-controlled variables: quantity and quality of irrigation water and frequency of irrigation. Data from the irrigation experiment show that situations exist in which increasing the depth of wetting lead to increasing salt concentration in the soil solution while at the same time decreasing the total and average soil water suctions.

72-73:03C-002
PRESENT AND FUTURE SALINITY OF THE COLORADO RIVER,
Holburt, M.B. and Valentine, V.E.
Colorado River Board of California, Los Angeles.
Paper, American Society of Civil Engineers, Hydraulics Division, Specifications Conference, University of Iowa, Iowa City, August 1971. 32 p, 3 fig, 7 tab, 8 ref, append.

Descriptors: *Salinity, *Irrigation effects, *Salt balance, *Water utilization, *Water pollution, Dissolved solids, Irrigation water, Reservoir evaporation, Saline water, Depletion, Forecasting, Inflow, Damages, Salts.
Identifiers: *Colorado River Basin, Colorado River Compact, Upper Colorado River Basin, Lower Colorado River Basin.

Colorado River salinity causes severe problems for irrigators in California and Arizona, some in the Upper Colorado River Basin, and affects the urban areas in southern California coastal plain. Continuing growth and development in the Colorado River Basin States will increase the river salinity substantially unless preventive measures are taken. Salinity of the river and its tributaries is caused by salts from natural and man-made sources, and by the consumptive use of water as it flows downstream. Irrigation is the predominant man-made activity that increases the river salinity. Evaporation from reservoirs and river salinity. Evaporation from reservoirs and river surfaces, and phreatophyte losses also have a significant impact on the salinity of the river. The 1970 salinity report of the Colorado River Board concluded that a combination of salinity control projects would reduce the river salinity. Approximately 2.8 million tons of salt per year could be removed from the river system if these control projects were constructed.

72-73:03C-003
INTERACTION OF TEMPERATURE AND SALINITY ON SUGAR BEET GERMINATION,
Fracois, L.E. and Goodin, J.R.
Agricultural Research Service, Riverside. Soil and Water Conservation Research Division.
Agronomy Journal, Vol 64, No 3, p 272-273, 1972. 1 tab, 1 fig, 11 ref.

Descriptors: *Environmental effects, *Salt tolerance, *Germination, *Limiting factors, *Thermal stress, Agriculture, Saline soils, Southwest U.S., Soil-water-plant relationships, Temperature, Salinity, Heat resistance, Physiological ecology, Plant physiology, *Sugar beets, Sugar crops.

Because high temperatures and soil salinity adversely affect sugarbeet germination in the southwestern United States, the interaction of temperature and salinity on germination was studied by a modification of the standard blotter technique. The interaction was highly significant. Salinity had little effect on germination at 10 degrees C and 15 degrees C but was increasingly inhibitory as temperature increased from 25 degrees C to 40 degrees C. Germination was maximum at 25 degrees C, with low salinity, and almost completely inhibited at 45 degrees C with all salinity levels. Of the four varieties studied, 'US-H2', 'US-H6', 'US-H8', and 'HH-5', germination of the US-H2 variety was most sensitive to salinity over the 30 degrees C to 40 degrees C range.

72-73:03C-004
SALT TOLERANCE OF SAFFLOWER VARIETIES DURING GERMINATION,
Ghorashy, S.R., Sionit, N., and Kheradnam, M.
Pahlavi University, Shiraz (Iran) College of Agriculture.
Agronomy Journal, Vol 64, No 2, p 256-257, March-April 1972. 1 fig, 8 ref.

Descriptors: *Salt tolerance, *Oilseed crops, *Germination, *Plant physiology, *Varieties, Crop response, Salinity, Saline soils, Growth chambers, Agronomic crops, Viability, Soil environment, Soil-water-plant relationships, Irrigation effects.
Identifiers: Plant section.

Safflower is an oil-seed crop well adapted to the semi-arid regions of the world. In these areas accumulation of salts in irrigated soils may reduce germination, growth, and eventually the yield of this crop. Varietal differences with respect to salt tolerance have been observed in various crop species. Knowledge of such differences in safflower is of potential importance. Effects of seven salinity levels (0 to 2 percent NaCl) on germination of three safflower varieties were determined under controlled temperature. The varieties were 'Ute', Iranian local 3151 showed the least reduction in percent germination, as compared with the other two at NaCl concentrations greater than 1 percent.

72-73:03C-005
SALINITY-OZONE INTERACTIONS ON PINTO BEAN: INTEGRATED RESPONSE TO OZONE CONCENTRATION AND DURATION,
Maas, E.V., Hoffman, G.J., Rawlins, S.L., and Ogata, G.
United States Department of Agriculture, Agricultural Research Service, Salinity Laboratory, Riverside, California.
Journal of Environmental Quality, Vol 2, No 3, p 400-404, July-September, 1973. 2 fig, 2 tab, 13 ref.

Descriptors: *Salinity, *Air pollution effects, *Air pollution, Plant growth, Beans, Leaves, Ozone, Oxidation, Osmotic pressure, Water pollution effects.

This investigation was conducted to determine the integrated effects of concentration and duration of ozone exposure on the injury, growth, and mineral composition of pinto bean during rapid vegetative growth and to evaluate the interactive effects of salinity. Plants were grown in controlled environment chambers in non-saline and two saline nutrient solution cultures having osmotic potentials of -0.4, -2.4, and -4.4 bars, respectively. Ozone-free plants were compared with plants treated daily for 2 weeks with ozone doses of from 0.15 to 0.90 ppm-hour. Plant injury and reduction in growth were sigmoidal functions of ozone dose. Plant tolerance thresholds were found for both concentration and duration of ozone exposure. Daily exposures above threshold levels produced cumulative injury that progressed from the primary leaves to subsequent trifoliate leaves. Although salinity suppressed plant growth, it extended the tolerance threshold for duration of ozone exposure and significantly reduced the injury by ozone. Ozone decreased Ca, Mg, K, and N contents of the leaves, increased stem contents of these elements, and had relatively little effect on root contents.

72-73:03C-006
INTERACTIVE EFFECTS OF SALINITY AND OZONE ON GROWTH AND YIELD OF GARDER BEET,
Ogata, G. and Maas, E.V.
United States Department of Agriculture, Agricultural Research Service, Salinity Laboratory, Riverside, California.
Journal of Environmental Quality, Vol 2, No 4, p 518-520, October-December, 1973. 2 tab, 12 ref.

Descriptors: *Air pollution, *Ozone, Salinity, Saline soils, Osmotic pressure, Soil chemical properties, Salt tolerance.

The interactive effects of root media salinity and ambient ozone on injury growth, and yield of garden beets were determined under controlled environmental conditions. Plants were grown in nonsaline and saline nutrient solution cultures having osmotic potentials of -0.4, -4.4, and -8.4 bars, respectively, and were exposed 5 weeks to 0.20 ppm ozone for 0 to 3 hours/day. Growth of the nonsaline beet plants were not significantly affected by 0.20 ppm ozone until exposure times exceeded 1 hour/day, although foliar injury in the form of a reddish-purple stipple had developed on mature leaves. Longer ozone exposures produced severe leaf necrosis and reduced the growth of tops and storage and fibrous roots as much as 50, 40, and 67%, respectively. In contrast, foliar ozone injury on plants grown in saline media developed more slowly and the growth of both tops and roots were relatively unaffected by ozone exposures of up to 3 hours/day. The beneficial effect of salinity in reducing ozone damage was offset by the suppressive effect of salinity on the yield of the storage root.

72-73:03C-007
GROWTH, MINERAL COMPOSITION, AND SEED OIL OF SESAME AS AFFECTED BY NaCl,
Yousif, Y.H., Bingham, F.T., and Yermanos, D.M.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Soil Science Society of America Proceedings, Vol 36, No 3, p 450-453, May-June, 1972. 2 fig, 4 tab, 20 ref.

Descriptors: *Salinity, *Crop response, Sodium, Chlorides, Seeds, Sodium chloride, Oilseed crops.

The tolerance of sesame to NaCl salinity was studied first during germination, and later during plant growth up to maturity. Germination was conducted in the laboratory at 25C. Sesame plants were tested for response to salinity using nutrient solution cultures with sodium chloride added when test plants were approximately 10 cm tall. Experiments were continues until mature seed pod formation. The data showed a high tolerance during germination but sensitivity at later growth stages.

72-73:03C-008
SALINITY, PLANT GROWTH, AND METABOLISM
Greenway, H.
Western Australia University, Nedlands. Department of Agronomy
Journal of the Australian Institute of Agricultural Science, Vol 39, No 1 p 24-34, March 1973. 6 fig, 2 diag., 3 tab, 61 ref.

Descriptors: *Salinity, *Plant growth, *Metabolism, Water utilization, Agriculture, Arid climates, Semiarid climates, Saline water, Plant physiology, Plant breeding, Electrolytes, Water shortage, Irrigation, Salt tolerance.

Water use for agricultural purposes, in arid and semiarid climates, usually implies the use of saline water. The challenge, then, is to increase the physiological tolerance of plants to saline water. Steps to improve agriculture in saline areas include: assessing large numbers of plant species for their response to salt; plant breeding for salt tolerance before further selection for other characteristics; and the understanding of causes for varietal differences in salt tolerance which for varietal differences in salt tolerance which would provide the basis for methods of selection at very early growth stages. Species should be evaluated in terms of causes for growth stimulations and growth reductions with the organism as a whole considered. Understanding how electrolytes and water deficits affect metabolism, along with information on growth and development should be the basis for further study in situations where either specific ion effects or water deficits are indications of salt injury. Physiological research should aim at the elucidation of the mechanisms of salt tolerance of various species especially if irrigation agriculture continues on a world wide scale. This research would further aid in understanding other biological issues, such as the physiology of marine organisms.

72-73:03C-009
SALINITY-OZONE INTERACTIVE EFFECTS ON YIELD AND WATER RELATIONS OF PINTO BEAN,
Hoffman, G.J., Maas, E.V., and Rawlins, S.L.
United States Department of Agriculture, Agricultural Research Service, Salinity Laboratory, Riverside, California.
Journal of Environmental Quality, Vol 2, No 1, p 148-158, January-March, 1973
4 fig, 2 tab, 16 ref.

Descriptors: *Salinity, *Air pollution effects, *Air pollution, Plant growth, Beans, Leaves, Ozone, Oxidation, Osmotic pressure, Water pollution effects.

The interaction of salinity and ozone on the growth of pinto bean was evaluated in a controlled temperature light room. Salinity treatments having osmotic potentials of -0.4, -2.0, and -4.0 bars were studied in combination with 2-hour daily exposures to 0, 0.15, 0.25, and 0.35 ppm of ozone. Ozone at 0.15 ppm decreased the yield of nonsaline plants nearly 50%; and at 0.25 ppm and higher, no significant yield was obtained. The results were essentially the same for plants salinized to -2.0 bars. At -4.0 bars, the yield was obtained. The results were essentially the same for plants salinized to -2.0 bars. At -4.0 bars, the yield at 0.25 ppm was only reduced to half that of the ozone-free treatment. The results indicate no intercation between salinity and ozone below 0.15 ppm. Above 0.15 ppm, however, there is a large interaction. At salinities of -0.4 and -2.0 bars, water-use efficiency decreased as ozone increased. Ozone did not appear to influence leaf water potential or its components.

Section XV

WATER SUPPLY AUGMENTATION AND CONSERVATION

CONSERVATION IN DOMESTIC AND MUNICIPAL USE (Group 03D)

72-73:03D-001
RETURN IRRIGATION WATER IN HAWAII,
Young, R.H.F., and Lao, C.
Water Resources Bulletin, Vol 9, No 3, p 538-   , June 1973.
(See 72-73:05B-088)

Section XVI

WATER SUPPLY AUGMENTATION AND CONSERVATION

CONSERVATION IN INDUSTRY (Group 03E)

72-73:03E-001
CHEMICAL METHOD OF PREVENTING LOSS OF INDUSTRIAL AND FRESH WATERS FROM PONDS, LAKES AND CANALS,
Rosene, R. V., and Parks, C. F.
Dow Chemical Company, Dowell Division.
Water Resources Bulletin, Vol. 9, No. 4, p 717-722, August, 1973. 2 fig, 5 ref.

Descriptors: *Seepage, *Seepage control, *Sealants, Polymers, Water loss, Groundwater, Impervious membranes, Leakage, Linings, Reservoir leakage, Soil sealants.

Preventing or markedly reducing the loss of aqueous fluids from a variety of reservoirs is becoming increasingly important. Fear of pollution from industrial waters and sewage impoundments as well as the economic factors involved in loss of fresh water add impact to this problem. This paper reviews the seriousness of the problem and methods that have been used to reduce loss of fluid are discussed. New materials for control of water loss are constantly being advocated, and chemical research has provided new systems that work extremely well. These systems, which combine unique chemicals and novel methods of application, are described. Specific case histories are included.

Section XVII

WATER SUPPLY AUGMENTATION AND CONSERVATION

CONSERVATION IN AGRICULTURE (Group 03F)

72-73:03F-001
SPRINKLING AND PONDING TECHNIQUES FOR RECLAMINING SALINE SOILS,
Oster, J.D., Willardson, L.S., and Hoffman, G.J.
Agricultural Research Service, Riverside, California.
Paper 72-210, 1972 Annual Meeting, American Society of Agricultural Engineers,
Hot Springs, Arkansas, June 1972. 7 p, 2 fig, 5 ref.

Descriptors: *Leaching, *Ponding, *Sprinkling, Soil conservation, Saline soils, Soil properties, Salinity, Percolation, Infiltration, Soil water movement, Rates of application, Efficiencies, On-site tests, California, Evaporation, Electrical conductance, Soil profiles.
Identifiers: *Soil reclamation, *Land reclamation, Imperial Valley (CA), Unsaturated flow, Field permeability tests, Sensors.

Reclaiming saline soil is usually accomplished by ponding for several months, despite evidence that intermittent ponding and sprinkling are more efficient in terms of water used. Salt displacement is most efficient under unsaturated flow. Using sprinklers, the application rate must be less than the maximum percolation rate to maintain unsaturated conditions. All experiment in the Imperial Valley, California, compared continuous ponding, intermittent ponding, and sprinkling techniques in 3 plots of 1150 sq m. Twelve salinity sensors monitored leaching in each plot. Electrical conductivity was standardized at 25 deg C. Soil salinity for the sprinkler plot did not change for 25 days because of low application rate and lag in moisture movement. Salinity reductions for all treatments was most rapid immediately after the first application for continuous and intermittent ponding and during initial stages of downward movement of water from sprinkling. Time required to reduce salinity by half was the same for the 3 leaching techniques. In terms of water used, intermittent ponding is most efficient, followed by sprinkling.

72-73:03F-002
SPRINKLER WATER DISTRIBUTION TESTING IN A DESERT ENVIRONMENT,
Hermsmeier, L.F.
Agricultural Research Service, Brawley, California. Imperial Valley Conservation Research Center.
Transactions of the ASAE, American Society of Agricultural Engineers, Vol 15, No 3, p 436-439, May-June 1972. 7 fig, 2 tab, 9 ref.

Descriptors: *Sprinkler irrigation, *Distribution patterns, *Agricultural engineering, *Analytical techniques, *Measurement,*Optimization, Arid lands, Agriculture, Irrigation systems, Irrigation design, Irrigation practices, Crop production, Water management (Applied), Farm management, Evaporation, Salinity, Testing procedures, Data collections, Irrigation efficiency.

In recent years sprinkler irrigation has become more widely practiced in many arid regions. In addition to providing water for crop growth, sprinklers are being used to apply water for a variety of specialized purposes including germination, salt control, frost protection and fertilizer and insecticide applications. Achieving uniform distribution, however, is particularly difficult with low application rate sprinklers because of their sensitivity to pressure, nozzle size, and spacing variables. A test facility for determining distribution patterns, evaporation losses and salt content changes of water for sprinkler irrigation has been constructed at the Imperial Valley Conservation Research Center, Brawley, California. Water from test sprinklers is caught in a series of catcher assemblies placed at 5-ft intervals in a square grid pattern. The test area size is 100 by 100 feet. Water for the system is supplied by a domestic water system, and uniform pressure is maintained with a booster pump and pressure regulator. Water is measured with a standard water meter. Windspeed and direction, air temperature, water temperature, and relative humidity are also measured. Sprinkler distribution patterns can be determined by one man in one-half hour plus sprinkler operation time with this system. Data collection is in the form of photographs which provide a visual representation of the distribution pattern and from which the amount of water on 0.01-in depth increments received at 50 feet square grid intervals in a 100-feet test area can be determined. The increase in time of operation for any given percentage of the field to receive a designed amount of irrigation water can be readily determined for any test condition.

72-73:03F-003
CENTER-PIVOT SPRINKLER DESIGN BASED ON INTAKE CHARACTERISTICS,
Dillon, R.C., Jr., Hiler, E.A., and Vittetoe, G.
Texas A&M University, College Station; and Soil Conservation Service, Temple, Texas.
Paper 71-759, American Society of Agricultural Engineers, 1971 Winter Meeting, Chicago, Illinois, December 1971. 27 p, 9 fig, 6 tab, 8 ref.

Descriptors: *Sprinkler irrigation, *Surface runoff, *Irrigation design, *Absorption, Design, Design criteria, Soil-water relationship, Water distribution (Applied), Water utilization, Irrigation efficiency, Root zone, Irrigated land, Characteristics, Crops, Rotation, Surface storage, Soil types, Slopes, Velocity, Irrigation.
Identifiers: *Water application rate, Soil storage capacities, Water retention, Soil-water relationship.

A procedure is developed enabling an engineer to design a center-pivot sprinkler irrigation system that will meet crop requirements without surface runoff. Equations are derived and design curves presented for determining peak water use, speed of travel, time per revolution, depth of application, discharge from water source, and length of the system. The procedure matches a system to a particular soil by determining the minimum speed of travel from the soil intake characteristics and the allowable surface storage. Potential runoff from the soil occurs when the allowable surface storage of the soil is satisfied. Values for the allowable surface storage for various slopes are given. Numerical values are given in the tables for: (1) peak water use rates for various crops, (2) irrigation efficiencies for various crops and climates, (3) feeder root depth of different crops, (4) soil storage capacity for different soils, and (5) sprinkler intake equations for different soils. This procedure is exemplified for a 180-acre square field.

72-73:03F-004
IRRIGATION PLANNING, 3. THE BEST SIZE OF IRRIGATION AREA FOR A RESERVOIR,
Dudley, J., Musgrave, W.F., Howell, T.
Montana State University, Bozeman. Department of Economics and Agricultural Economics.
Water Resources Research, Vol 8, No 1, p 7-17, February 1972. 5 fig, 3 tab, 3 ref.

Descriptors: *Simulation analysis, *Irrigation programs, *Irrigation systems, *Decision making, *Reservoirs, *Stochastic processes, *Water supply, *Water demand, *Fixed costs, *Model studies, Costs, Systems analysis, Long-term planning.
Identifiers: Corn

A simulation model was used to determine the best-sized area to develop for irrigation in conjunction with a given dam. The model was applied to a hypothetical situation involving the irrigation of a single crop, corn. It was assumed that releases from the given reservoir, the acreage to be planted, and irrigation timing were all controlled by one decision maker. Short-run models were used to estimate the best area to plant and the best way to allocate a quantity of water given a stochastic demand and supply. The results of the short-run models were incorporated into the long-run simulation model. The solutions of the simulation model were highly sensitive to changes in total fixed costs. The costs of applying the model are likely to be much less than the penalty of choosing suboptimal acreages. The models are capable of being elaborated to assist decision making in more complex systems that considered in this paper.

72-73:03F-005
ONE APPROACH TO IRRIGATION MODELING UNDER RISK,
Smith, D.V.
Harvard University, Cambridge, Massachusettes, Center for Population Studies.
Water Resources Bulletin, Vol 8, No 6, p 1225-1234, December 1972. 46 equ,
21 ref.

Descriptors: *Irrigation, *Planning, *Water supply, *Stochastic processes, *Linear programming, *Optimization, Water demand, Water balance, Wells, Canals, Rainfall, Streamflow, Mathematical models, Systems analysis.
Identifiers: *Uncertainty, *Water deficits, *Risk levels, Cropping patterns, Chance-constrained programming.

To demonstrate the strengths and weaknesses of stochastic programming with recourse, a problem in irrigation planning is considered. It is based upon a deterministic planning model and a series of stochastic planning models that build upon a project area water balance, to evaluate the irrigated area to be developed, the cropping pattern to be selected, and the required capacities of the well and canal systems; it is assumed that there is no surface reservoir storage of water. Stochastic programming with recourse is shown to have considerable potential for modeling a complex irrigation problem under conditions of random rainfall and streamflow. Its utility will grow as computational techniques are improved for solving multistage stochastic programming with recourse problems, and as agronomists provide the necessary loss functions for water deficits.

72-73:03F-006
IRRIGATION PLANNING 4, OPTIMAL INTERSEASONAL WATER ALLOCATION,
Dudley, N.J.
Montana State University, Bozeman Department of Economics; and Montana State University, Bozeman. Department of Agricultural Economics.
Water Resources Research, Vol 8, No 3, p 586-594, June 1972. 4 tab, 4 ref.

Descriptors: *Irrigation engineering, *Irrigation operation and maintenance, *Acreage, *Irrigation water, *Water transfer, *Water supply, Water demand, Water consumption, Reservoirs, Seasonal, Dynamic programming, Simulation analysis, Optimization, Estimating, Benefits, Net profit, Decision making, Systems analysis, Soil moisture, *Model studies.
Identifiers: *Reservoir water, *Interseasonal transfer, *Interseasonal water allocation, Computer output.

A series of models has been developed in previous papers to estimate the best sized area to develop for irrigation from a given reservoir under conditions of variable supply and demand for irrigation water. The most economically feasible operating policies for such a system were also derived. The previous approach is extended by recognizing the value of water carried over from one season to the next. A modified version of the previous approach is used to generate reservoir level transition probabilities and expected benefits. A dynamic programming model is then used to estimate the expected benefits from allocating water optimally between seasons. These expected benefits are a function of acreage developed for irrigation and beginning-season reservoir levels. Such a function allows a decision maker at any decision point within an irrigation season to equate the expected net benefits from allocating water to the rest of the current season with the expected net benefits from saving such water for the following season. This decision-making process is simulated for a number of seasons. The results of an application of the models indicate that such interseasonal transfer can considerably increase the present value of expected benefits from the project.

72-73:03F-007
OPTIMAL IRRIGATION QUANTITY AND FREQUENCY,
Wu, Ipai and Liang, T.
Hawaii University, Honolulu Department of Agricultural Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 98, No IR1, Paper 8776, p 117-133, March 1972. 10 fig, 4 tab,
2 ref.

Descriptors: *Optimization, *Irrigation practices, *Operations research, Mathematical models, Cost analysis, Soil moisture, Vegetable crops, Evapotranspiration, Tensiometers, Rots, Field capacity, Lettuce, Hawaii, *Irrigation efficiency, *Crop production.
Identifiers: Celery

Mathematical models are derived to aid in selecting optimal soil moisture levels for maximum crop yield in irrigation farming. Minimum irrigation cost over the entire growth period is selected as the principal criterion for determining optimal irrigation practices. Optimal irrigation frequency and quantity needs vary between different crops. Evaluation of the models indicates that these specific needs can be determined when irrigation costs and average consumptive use are known. Major irrigation cost consists of the expense in purchasing and delivering water and the economic losses caused by crops grown under unfavorable soil moisture conditions. The models are based upon two different irrigation practices: (1) Soil moisture kept equal or below the optimal soil moisture and (2) Soil moisture allowed to fluctuate above or below the optimal soil moisture. A technique for assessing optimal soil moisture, crop yield and cost functions is further developed from irrigation experiments in Hawaii with lettuce and celery. Results show that lettuce produces its maximum yield at soil moisture less than field capacity This demonstrates that general irrigation practices, irrigating to field capacity, is not always the optimal irrigation schedule.

72-73:03F-008
PREDICTION OF IRRIGATION ADVANCE FUNCTION BY DIMENSIONAL ANALYSIS,
Sastry, G., and Agarwal, S.C.
Indian Institution of Tech., Kharagpur, Department of Agricultural Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Proceedings, Vol 98, No IR2, p 247-253, June 1972. 2 fig, 12 ref.

Descriptors: *Irrigation, *Dimensional analysis, *Computers, *Field capacity, Mathematical studies, Hydraulic conductivity, Forecasting, Inflow, Soil types, Infiltration, Soil water movement.

One of the important factors in the design of a surface irrigation system is the prediction of the advance distance-time relationship when estimating in advance for a given entrance stream size and land surface slope under given soil bed infiltration characteristics variation. An attempt has been made to derive an advance equation by dimensional analysis of the fundamental variables involved in water advance phenomena. Dominant variables considered include distance of advance, elapsed time, inflow stream per unit top width of flow, slope of soil bed, acceleration due to gravity, exponent in the in the Kostiakov type accumulated infiltration function, hydraulic conductivity of soil bed and absolute roughness of the bed. With available field data, the derived equation was tested and found satisfactory. Using the proposed technique, a general equation can be derived with suitable experimentation.

72-73:03F-009
ATTAINABLE IRRIGATION EFFICIENCES,
Willardson, L.S.
Agricultural Research Service, Brawley, California. Imperial Valley Conservation Research Center.
Journal of Irrigation and Drainage Division, American Society of Civil Engineers, Vol 98, No IR2, p 239-246, June 1972. 1 fig, 2 tab, 15 ref.

Descriptors: *Irrigation efficiency, *Root zone, *Uniformity coefficient, *Irrigation systems, Economic feasibility, Political aspects, Infiltration rates, Soil water movement, Sprinkler irrigation.
Identifiers: *Trickle irrigation

The general objective of irrigation is to provide a suitable moisture environment in the soil for plant growth. Since water supplies for irrigation in the arid and semiarid western U.S. have never been as plentiful as irrigators would like, the concept of irrigation efficiency has received much attention. Irrigation efficiency is considered equivalent to water application efficiency or

72-73:03F-010
WATER DEFICITS-IRRIGATION DESIGN AND PROGRAMMING,
Hagan, R.M., and Stewart, J.I.
California University, Davis, Department of Water Science and Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 98, No IR2, p 215-237, June 1972. 2 fig, 2 tab, 124 ref.

Descriptors: *Irrigation practices, *Evapotranspiration, *Planning, *Peak loads, *Irrigation programs, Soil moisture, Soil-water plant relationships, Moisture tension, Moisture deficit, Productivity, Economic feasibility, Crop response.
Identifiers: *Water use efficiency, *Production functions, *Plant water potential.

Irrigation systems are created with the intention of providing water to crops to prevent the occurrence of crop water deficits that will lead to uneconomic yields. Design engineers must deal with the problem of matching the capacities of water distribution and water application to the peak use rates indicated by the peak evaporation rates. Water use efficiency is a prime goal because building increased capacity into distribution and application systems is very expensive. Economic information is needed on the expected effects of water deficits on crop yields, which is unfortunately scarce. Two approaches to irrigation programming and design of irrigation system peak capacities to meet delivery and application requirements are presented. The first is a comprehensive tabulation of available data on allowable soil water suction. This updates and adds to earlier information. Much of the data shows considerable scatter and it is obvious that plant water deficits would be better described by plant water potential rather than soil moisture. The conditions of evaporative demand complicate any interpretation of soil moisture in terms of plant moisture stress. The second approach is a continuing research program on preseason irrigation programming techniques and development of water production functions for principal crops, relating yield reductions to water deficits. These functions will vary with type of crop, soil depth and water holding capacity. Evaporative demand of the area in question, and with the particular program adopted for times and depths of water applications.

72-73:03F-011
DISTRIBUTION CHANNELS WITH MULTIPLE OUTLETS,
Hart, W.E., and Borrelli, J.
Colorado State University, Fort Collins, Department of Agricultural Engineering; and Pennsylvania State University, University Park, Department of Civil Engineering.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 98, No IR2, p 267-274, June 1972. 2 fig, 1 tab, 8 ref.

Descriptors: *Semiarid climates, *Distribution systems, *Channels, *Irrigation systems, Spillways, Furrow irrigation, Ditches, Economic feasibility, California, Outlets, Hydraulic structures, Slopes.

Land use improvements in California require agricultural intensification in some portion of the state's approximate 8 million acres of rolling dry foothills. An obvious first step would be irrigated pasturelands, but the economics of such land development dictate an irrigation system with low labor, capital and water requirements. The practical solution to these requirements is a graded supply ditch in which the water is checked at intervals to form bays. When a given bay is checked, the total supply flow is diverted through multiple, equally spaced outlets into field corrucations. The corrugation system is designed to allow simultaneous discharge from several identical outlets equally spaced along a graded open supply ditch. Design procedures for the bays and outlets under a wide set of field conditions are outlined. In order to insure approximately equal outflow from each of the several operating outlets, it is necessary that the head on all outlets be nearly equal. The required minimum head can be estimated using the gradually and rapidly varied flow equations. The design of zero-slope channels is also discussed.

72-73:03F-012
IRRIGATION THROUGH SUBSURFACE DRAINS,
Skaggs, R.W., Kriz, G.J., and Bernal, R.
North Carolina State University, Raleigh
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers; Vol 98, No IR3, p 363-373, September 1972. 8 fig, 11 ref, append.

Descriptors: *Subsurface irrigation, *Theoretical analysis, On-site investigations, Hydraulic conductivity, Subsurface drains, Groundwater movement, Permeability, Irrigation systems, Evapotranspiration, Soil water movement, Drainage effects, Steady flow, North Carolina, Impervious soils, Water table, Irrigation, Loam.
Identifiers: *Drain spacing, Sandy loams, Tile spacing.

Subirrigation aims at raising and maintaining the water table to a level sufficient to supply the water needs of a crop. Management of the water table is dependent upon: (1) an impermeable layer or a permanent water table at shallow depth to minimize seepage losses; (2) topography nearly flat so that the supply is uniformly available in a field; and (3) soil having a high hydraulic conductivity. Feasibility of subirrigation was investigated on 12 tile lines 12.5 cm in diameter, in sets of 4, with 7.5 m, 15 m, and 30 m spacings. The soil was 20-30 cm of sandy loam underlain by a tight clay layer. Results showed that water could be supplied successfully for all but the 30 m spacing. Theory showed that a water table 30 cm above the tile could be maintained midway between lines with a spacing of 19.2 m. An equation was derived for upward movement of the water table during the early stages of subirrigation. Comparisons with field tests showed the equation to be accurate for predicting the rise midway between tile lines.

72-73:03F-013
IRRIGATION MANAGEMENT--A TOOL FOR AGRIBUSINESS,
Schild, N.W., and Nelson, Jr., H.R.
Bureau of Reclamation, Denver, Colorado. Water Operations Branch.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 98, No IR3, Paper 9211, p 347-361, September 1972. 7 fig, 3 tab, 10 ref.

Descriptors: *Irrigation operation and maintenance, *Irrigation efficiency, *Management, *Computers, Agricultural engineering, Soil moisture, Water distribution (Applied), Reclamation, Water resources, Crops, Optimum development plans.
Identifiers: *Agribusiness, *Jensen-Haise method, *Climatic parameters, Crop consumptive use.

Irrigation Management is a tool whereby timely application of water can improve irrigation efficiencies. Irrigation Management has been made possible by adaptation of a computer program to the Jensen-Haise method of computing crop consumptive use. A daily soil moisture level balance is available by inserting climatic parameters for a computer printout at a specific time. These printouts are presented to irrigators who can be shown when the next irrigation application will be required for a specific field. This will improve irrigation efficiencies because the water will be applied when the soil moisture level is deficient. Data previously collected indicated that irrigators were unaware of soil moisture levels when applying water. Irrigation Management Services being conducted by Bureau of Reclamation personnel in Kansas and Wyoming are presented. Data for the Irrigation Management have been analyzed showing results during 1971. The future of Irrigation Management is exploited and incorporated with operation of irrigation systems.

72-73:03F-014
PLANNING AND UPDATING FARM IRRIGATION SCHEDULES,
Buras, N., and Pistun, A.M.
Technion - Israel Institution of Technology, Haifa. Lowdermilk Faculty of Agricultural Engineering
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 99, No IR1, Proceedings paper 9586, p 43-51, March, 1973. 5 fig, 8 ref, 2 append.

Descriptors: *Irrigation, *Irrigation engineering, *Irrigation programs, *Scheduling, *Management, Simulation analysis, Digital computers, Optimum development plans, Water resources, Soil moisture, Agriculture, Crops, Farms, Water supply, Distribution, Networks, Planning, Climatic data, Hydraulics, Systems analysis, Mathematical models.

The optimal scheduling of irrigation activities is a considerably complex problem, requiring a large computational effort. Digital computers are useful in the planning process. A computer program is developed for the planning of irrigation schedules within the broader context of agricultural production, and for the updating of these schedules whenever necessary. The computer program, which is oriented toward solving problems arising during the busy irrigation season, is a simulation algorithm which schedules the application of water on the basis of soil moisture balances at given intervals of time. The irrigation requirements are then checked against the hydraulic characteristics of the farm water distribution system. Delays in replenishing the moisture deficiency within the root zone generate losses which are functions of the magnitude of the delay and of the vegetative status of the crop. The alternative schedule which minimized these losses is selected. The program has the advantage that it allows the planning of farm irrigation schedules to progress in stages; as current information regarding climatic and soil conditions, water supply, agrotechnical practices, and marker conditions becomes available, the initial schedule can be quickly updated so as to reflect the changing environmental conditions.

72-73:03F-015
SOIL NITROGEN BALANCE IN SELECTED ROW-CROP SITES IN SOUTHERN CALIFORNIA,
Adriano, D.C., Takatori, F.H., Pratt, P.F., and Lorenz, O.A.
California University, Riverside, Department of Soil Science.
J Environmental Quality, Vol 1, No 3, p 279-283, 1972. Illus.

Identifiers: *California, Crops, Sites, Denitrification, Drainage, *Fertilization, Irrigation, Nitrate, *Nitrogen, Soils, Row crops.

Nine row-crop sites, where data for N fertilizer use, crop yields, and amounts of irrigation water used were available for a number of years, were studied to estimate the N balance as related to No-3 in water in the unsaturated zone from below the zone of root influence to the water table or to the 15-m depth. The system of predicting NO3-concentrations in drainage waters based on the difference between N inputs and N removal in harvested crops and the drainage volume in which the excess N, converted to NO3-, is dissolved, was valid in open-porous soils containing no layers that restrict water movement within the soil profile (0 to 2-m depth). A combination of losses plus net immobilization of up to 56% had to be assumed in some soils to account for all the N loss. In 2 soils that had been used for disposal of feedlot manure, net mineralization of N from the organic N pool had to be assumed to explain the data obtained. The current fertilization and irrigation practices used for some row crops in southern California leave varying amounts of NO3- in the drainage water. The amounts depend on the total N added, crop removal, drainage volume, net mineralization and losses.

72-73:03F-016
CONSTRAINTS IN WATER MANAGEMENT ON AGRICULTURAL LANDS,
Radosevich, G.E., Vlachos, E.C., and Skogerboe, G.V.
Colorado State University, Fort Collins. Department of Economics.
Water Resources Bulletin, Vol 9, No 2, p 352-359, April 1973.

Descriptors: *Water management (Applied), *Irrigation, *Administration, *Social aspects, *Water law, *Water policy, Irrigation practices, Irrigation districts, Social values, Return flow, Water rights, Water quality control, Constraints.

Whether the goal is minimizing water quality degradation in receiving streams of maximizing agricultural production on existing croplands, the solutions are identical--improved water management practices. Technology has succeeded in developing feasible solutions to improvement of irrigation water management, but the law has been slow to direct or encourage implementation. The

72-73:03F-012
IRRIGATION THROUGH SUBSURFACE DRAINS,
Skaggs, R.W., Kriz, G.J., and Bernal, R.
North Carolina State University, Raleigh
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers; Vol 98, No IR3, p 363-373, September 1972. 8 fig, 11 ref, append.

Descriptors: *Subsurface irrigation, *Theoretical analysis, On-site investigations, Hydraulic conductivity, Subsurface drains, Groundwater movement, Permeability, Irrigation systems, Evapotranspiration, Soil water movement, Drainage effects, Steady flow, North Carolina, Impervious soils, Water table, Irrigation, Loam.
Identifiers: *Drain spacing, Sandy loams, Tile spacing.

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72-73:03F-013
IRRIGATION MANAGEMENT--A TOOL FOR AGRIBUSINESS,
Schild, N.W., and Nelson, Jr., H.R.
Bureau of Reclamation, Denver, Colorado. Water Operations Branch.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 98, No IR3, Paper 9211, p 347-361, September 1972.
7 fig, 3 tab, 10 ref.

Descriptors: *Irrigation operation and maintenance, *Irrigation efficiency, *Management, *Computers, Agricultural engineering, Soil moisture, Water distribution (Applied), Reclamation, Water resources, Crops, Optimum development plans.
Identifiers: *Agribusiness, *Jensen-Haise method, *Climatic parameters, Crop consumptive use.

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72-73:03F-014
PLANNING AND UPDATING FARM IRRIGATION SCHEDULES,
Buras, N., and Pistun, A.M.
Technion - Israel Institution of Technology, Haifa. Lowdermilk Faculty of Agricultural Engineering
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 99, No IR1, Proceedings paper 9586, p 43-51, March, 1973. 5 fig, 8 ref, 2 append.

culprit of the western United States water problem is the property right concept of the appropriation doctrine. The most substantial impact in solving the legal and other institutional constraints inherent in the appropriation doctrine would be more stringent application of the beneficial use concept. Moreover, water quality should be made a part of each water right, the appurtenancy concept, which ties water to land, should be eliminated, and water laws should be modified to encourage the renting, leasing, transferring or selling of water rights to other uses and places so long as the vested rights of others are protected. Improving water management also implies organizational improvements such as increasing project irrigation efficiency and effectiveness through consolidation of fragmented irrigation and drainage districts into valley-wide single management units. All attempts for modifying water use must be guided by a pervasive spirit of social consciousness.

72-73:03F-017
SYSTEMS ANALYSIS AND IRRIGATION PLANNING,
Smith, D.V.
Harvard University, Cambridge, Massachusettes, Center for Population Studies.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol 99, No IR1, Proceedings paper 9625, p 89-107, March, 1973.
2 fig, 2 tab, 64 ref.

Descriptors: *Irrigation, *Irrigation programs, *Project planning, *Systems analysis, Optimization, Linear programming, Stochastic processes, Economic analysis, Agriculture, Groundwater, Water resources, Mathematical models, Hydrology, Dynamic programming.
Identifiers: Deterministic models.

Certain concepts and techniques of systems analysis can aid irrigation planning in poor countries that have social and physical environments radically different from those found in industrialized nations with extensive irrigation practice. An ample literature survey is followed by description of the basic deterministic planning model, a model emphasizing the interactive consequences of cropping pattern selection, conjunctive use of ground and surface water, and employment of wells as water table control devices. Stochastic parameters are introduced into the model to improve its representation of reality and to interpret meaningfully the consequences for stochastic variability. Various factors favor the use of the chance-constrained approach to stochastic programming. Unlike previous applications, general distribution functions, variable capacities, piecewise linear decision rules, and stochastic demands and supplies are dealt with.

72-73:03F-018
SYSTEMS ANALYSIS IN IRRIGATION AND DRAINAGE,
Hall, W.A.
Cwlifornia University, Riverside, Dry-Lands Research Institution.
Journal of the Hydraulics Division American Society of Civil Engineers, Vol 99, No HY4, Proceedings paper 9659, p 567-571, April 1973. 5 p.

Descriptors: *Irrigation, *Drainage, *Systems analysis, *Soil moisture, Water resources, Decision making, Foods, Crops, Hydraulics, Agriculture, Plants, Nutrients, Optimization, Streamflow, Risks, Alternative planning, Mathematical models, Water rights, Water demand, Water costs, Water shortage, Salinity, Droughts, Irrigation water.

It is imperative that water engineers and planners utilize systems in order that costly irreversible water decisions may be based upon sound judgments. Growing population, problems of inadequate nutrition, and rising standards of living all demand increases in food production. The rate of increasing agricultural productivity cannot be maintained by continued use of fertilizer, pest control, and genetics; only irrigation and its correlative drainage can be counted on for certain to increase food and fibre supplies. But water shortages and resulting high costs pose great difficulties. Because of such food production and water cost squeezes, and a serious political squeeze wherein potential water for agriculture is given to cities, irrigation and drainage must be brought to a point of maximum efficiency. Needed is a new technology for agricultural water use based on systems analysis, for: (1) precision control of soil moisture related factors of production; (2) optimization of the use of unregulated stochastic streamflows; (3) optimization of risk and return from water use under uncertainty; and (4) optimal salinity and drought strategies. This step must be taken, regardless of important analytical limitations and considerable additional fundamental research requirements.

72-73:03F-019
SPRINKLING AND PONDING TECHNIQUES FOR RECLAIMING SALINE SOILS,
Oster, J.D., Willardson, L.S., and Hoffman, G.J.
Agricultural Research Service, Riverside, California.
Paper 72-210, 1972 Annual Meeting, American Society of Agricultural Engineers, Hot Springs, Arkansas, June 1972. 7 p, 2 fig, 1 tab, 5 ref.

Descriptors: *Leaching, *Ponding, *Sprinkling, Soil conservation, Saline soils, Soil properties, Salinity, Percolation, Infiltration, Soil water movement, Rates of application, Efficiencies, On-site tests, California, Evaporation, Electrical conductance, Soil profiles.
Identifiers: *Soil reclamation, *Land reclamation, Imperial Valley (CA), Unsaturated flow, Field permeability tests, Sensors.

Reclaiming saline soil is usually accomplished by ponding for several months, despite evidence that intermittent ponding and sprinkling are more efficient in terms of water used. Salt displacement is most efficient under unsaturated flow. Using sprinklers, the application rate must be less than the maximum percolation rate to maintain unsaturated conditions. An experiment in the Imperial Valley, California, compared continuous ponding, intermittent ponding, and sprinkling techniques in 3 plots of 1150 sq m. Twelve salinity sensors monitored leaching in each plot at depths of 53 cm and 86 cm at 3 positions on the centerline of each plot. Electrical conductivity was standardized at 25 deg C. Soil salinity for the sprinkler plot dit not change for 25 days because of low application rate and lag in moisture movement. Salinity reduction for all treatments was most-rapid immediately after the first application for continuous and intermittent ponding and during initial stages of downward movement of water from sprinkling. Time required to reduce salinity by half was the same for the 3 leaching techniques. In terms of water used, intermittent ponding is most efficient, followed by sprinkling.

72-73:03F-020
WHEAT RESPONSE TO SOIL MOISTURE AND THE OPTIMAL IRRIGATION POLICY UNDER CONDITIONS OF UNSTABLE RAINFALL,
Yaron, D., Strateener, G., Shimshi, D., and Weisbrod, M.
Hebrew University, Jerusalem (Israel)
Water Resources Research, Vol 9, No 5, p 1145-1154, October 1973. 2 fig, 6 tab, 17 ref.

Descriptors: *Irrigation efficiency, *Soil moisture, *Rainfall, *Stochastic processes, *Simulation analysis, *Decision making, *Optimum development plans, Computer models, Estimating, Irrigation practices, Crops, Water management (Applied), Systems analysis, Risks.
Identifiers: *Wheat yield, Irrigation policy.

Presented is a method for estimating a response function of wheat yield to soil moisture and for determining the optimal irrigation policy under conditions of stochastic rainfall. To determine such policy, information on the variation of the soil moisture over time as a function of depth is needed. A low-cost, computer simulation, soil moisture estimation model designed to reconstruct the soil moisture fluctuations (during the growing season of wheat) on the basis of incomplete data is described. Then, empirical estimates of the response function of wheat yield derived on the basis of a four-year irrigation experiment are presented; use is made of the Mitscherlich function. For the problem of deriving the optimal irrigation policy under conditions similar to those in the experiment (unstable rainfall), the soil moisture estimation model and the estimate of the Mitscherlich response functions have been applied in an analysis in which the rainfall record representing the random rainfall distribution at the experiment site for a period of 16 years is taken into account. Two approaches are compared by simulating their consequences in relation to the 16-year rainfall record.

72-73:03F-021
STOCHASTIC RESERVOIR MANAGEMENT AND SYSTEM DESIGN FOR IRRIGATION,
Dudley, N.J. and Burt, O.R.
New South Wales University, Kensington (Australia). School of Economics.
Water Resources Research, Vol 9, No 3, p 507-522, June. 1973. 3 fig, 22 ref.

Descriptors: *Stochastic processes, *Reservoirs, *Management, *Design, *Irrigation, *Dynamic programming, Crops, Optimization, Simulation analysis, Irrigation efficiency, Estimating, Water resources development, Acreage, Value, Benefits, Decision making, Systems analysis, Mathematical models, Variability
Identifiers: Design variables, Interseasonal, Intraseasonal, Intertemporal, Water application rates, Reservoir capacity, Distribution systems.

An integrated intraseasonal and interseasonal stochastic dynamic programming model is developed to determine an optimal decision rule with respect to the following classes of crop irrigation decisions: (1) intertemporal water application rates (2) whether or not some acreage should be relinquished from further irrigations for the remainder of the season; and (3) the optimal acreage to plant for potential irrigation at the beginning of the season. Solutions of the problem are shown to be a basis for optimizing the levels of three design variables: Developed irrigation acreage, reservoir capacity, and distribution system capacity. A method is presented for incorporating variance, as well as expected value, of the net benefits into the decision criterion for optimal developed acreage. An application is made to a simplified real situation in which optimal acreage to develop is the only design variable. State variable transition probabilities are calculated by a simulation model. A significant trade-off is found between expected net benefits and their variability in determination of the optimal developed acreage for irrigation.

72-73:03F-022
EFFECT OF IRRIGATION, HARVEST INTERVAL, AND NITROGEN ON THE YIELD AND NUTRIENT COMPOSITION OF NAPIERGPASS,
Capiel, M, and Ashcroft, G.L.
Puerto Rico University, Mayaguez. Agricultural Experiment Station.
Agronomy J. Vol 64, No 3, p 396-398, 1971

Studies were conducted in a subhumid area of Puerto Rico to investigate the main effect and the interrelations of harvest interval, irrigation, and N fertilization on the yield and nutrient composition of napiergrass. Harvest interval exerted the main effect on the dry matter yield of the forage. N fertilization and irrigation also had highly significant effects. Irrigation interacted significantly with harvest interval to influence forage yield. The increase in yield as a result of a longer harvest interval was nearly 92% greater on irrigated than on nonirrigated plots. N fertilization produced a highly significant increase in the protein yield of this forage. No other management treatment appreciably influenced protein yields. Significant negative correlations were obtained between yield and both N and K composition for the forage on the frequently harvested, irrigated plots. Both nutrients were at lower concentration in the forage produced in harvest periods that had high yields.

72-73:03F-023
PATTERNS OF WATER UPTAKE AND ROOT DISTRIBUTION OF SOYBEANS IN THE PRESENCE OF A WATER TABLE,
Reicosky, D.C., Millington, R.J., Klute, A., and Peters, D.B.
Agricultural Research Service, Urbana, Illinois. Soil and Water Conservation Research Division.
Agronomy Journal, Vol 64, No 3, p 292-297, May-June 1972. 7 fig, 2 tab, 13 ref.

Descriptors: *Moisture uptake, Root systems, *Root distribution, *Absorption, Soil-water-plant relationships, *Capillary fringe, *Soil water movement, *Hydraulic conductivity, Water table, Crop production, Movement, Soil water, Soils. Limiting factors, Plant growth, Plant physiology, Plant morphology, Soil science, Soil tests, Fringe water, *Soybeans.

The increasing importance of water use in crop production has demonstrated the need for integrated studies of water transport phenomena in the soil-plant-atmosphere system. A better understanding of the basic principles involved can lead to better management techniques for efficient water use. The purpose was to measure water uptake patterns of soybeans and relate these to root distribution and water uptake per unit root length. Water uptake in soil columns was analyzed using the flow equations for water movement in the soil, treating the root system as a macroscopic sink. Results indicate that in the presence of a water table, water uptake was not necessarily related to root distribution and that a small amount of roots near the capillary fringe absorbed most of the water. Results also showed the combined importance and interaction of the hydraulic conductivity and the root distribution in determining the magnitude and the distribution of the sink term. Both of these factors limited the rate of uptake. As the plants grew, both increased water uptake per unit root length and increase in the length of roots contributed to meeting the rising daily rate of water use.

72-73:03F-024
REFLECTED RADIATION FROM A SOYBEAN CROP,
Blad, B.L. and Baker, D.G.
Nebraska University, Lincoln. Department of Horticulture and Forestry.
Agronomy J. Vol 64, No 3, p 277-280, 1972 Illustration.

Identifiers: *Solar radiation, Albedo, Crops, Eppley, Glycine max D, Lodging, Moisture, Pyranometer, Radiation, Soils, *Soybeans.

The albedo, defined as the percentage of incoming solar radiation that is reflected, was measured continuously over a soybean crop (Glycine max. (L.) Merr.) during the 1968, 1969, and 1970 growing seasons at St. Paul, Minnesota. The study was undertaken to establish average albedo values for soybeans and to evaluate the effects of increasing crop cover on the albedo. The average daily albedo ranged from 24%-27% with complete soybean cover. The albedo of the moist soil was approximately 10.5% with no cover and increase in crop cover. Because this relationship held true over the entire growing season, it should be possible to accurately estimate soybean cover from albedo measurements once the growth characteristics of a variety have been established. It was also possible during the study to examine the effects of soil moisture and lodging on the soybean albedo. With full cover the albedo decreased at low soil moisture because the soybean leaves wilted and became more vertically oriented, thereby permitting increased penetration of incoming solar radiation. Before canopy closure, particularly early in the season, low soil surface moisture caused a marked increase in albedo. Severe lodging during mid-Aug. 1970 caused a marked decreasein albedo. Failure to properly shield the inverted Eppley pyranometer was shown to cause an increase in the daily average albedo of as much as 7.5% because of internal reflection from the pyranometer dome. An average albedo of 25.9% was obtained for 2 clear days. It was noted on these days that morning albedoes were higher than evening albedoes at the same solar altitudes. This was attributed to temporarily wilted, drooping leaves, and to increased leaf flutter from stronger afternoon winds. The average daily albedo for 2 cloudy days was 24%.

72-73:03F-025
INFLUENCE OF THREE CUTTING SYSTEMS ON THE YIELD, WATER USE EFFICIENCY, AND FORAGE QUALITY OF SALINFOIN,
Koch, D.W., Dotzenko, A.D., and Hinze, G.O.
Colorado State University, Fort Collins, Department of Agronomy.
Agronomy Journal, Vol 64, No 4, p 463-467, July-August 1972. 2 fig, 6 tab.

Descriptors: *Crop production, *Water utilization, *Consumptive use, *Forage grasses, *Legumes, Efficiencies, Evapotranspiration, Drought resistance, Digestion, Colorado, Semiarid climates, Great Plains, Mature growth stage, Alfalfa, Proteins, Cattle, Plant growth regulators, Rainfall, Temperature, Wind velocity, Evaporation, Dry farming, Moisture stress, Calcium, Magnessium, Leaves, Cellulose, Linings, Potassium.
Identifiers: *Sainfoin, *Cutting systems, Dry matter, Perennial grasses, Maturation, Stems, Hemicellulose, Cell wall constituents.

Though few perennial legumes are well adapted to the semiarid environmental conditions in the Central Great Plains, Sainfoin is one that compares well with alfalfa productivity, and contains similar available energy to meet protein requirements of beef animals. Sainfoin is a nonbloating, fairly drought-tolerant forage. Yield, water-use efficiency and forage quality are reported of sainfoin grown under climatic conditions that are typically semiarid and characterized by erratic rainfall, extremes in temperature, high average wind velocity, and high evaporation rates. Field experiments were performed at the Central Great Plains Field Station at Akron, Colorado, to determine the potential of Sainfoin as a dryland forage crop. Despite below-average rainfall, yields were 3,494 and 2,383 Kg/ha dry matter for 1969 and 1970, mostly produced by the first cutting. Water-use efficiency was high for the first, but low for the second cutting due to slow regrowth. Roots extracted soil moisture from 180 cm under lateseason moisture stress due to prolonged drought. Survival rate over the 2-year period was lower for plants harvested consistently at the early bloom stage. Leaf, protein, and mineral percentages, cell wall components, and in vetro dry matter digestibility decreased little during maturing because of high retention of leaves and rapid maturation. Leaves had high percentages of protein, in vitro digestibility, Ca and Mg, and had lower percentages of cellulose, hemicellulose, lignin, cell wall constituents and K than stems. Sainfoin is an efficient water user and can survive moisture stress adequately.

72-73:03F-026

INFLUENCE OF LEVELS OF SPRING IRRIGATION AND FERTILITY ON YIELD OF WINTER WHEAT (TRITICUM AESTIVUM L) UNDER SEMI-ARID CONDITIONS.

Poostchi, I., Rovhani, l., and Razmi, K.
Pahlavi University, Shiraz (Iran), Department of Crop Science.
Agronomy Journal, Vol. 64, No. 4, p 438-440, July-August 1972. 3 tab, 12 ref.

Descriptors: *Crop production, *Spring, *Irrigation, *Fertility, *Wheat, Variability, Semiarid climates, Fluctuations, Seasonal, Plant growth regulators, Nitrogen, Phosphorus, Soil moisture, Proteins, Grains (Crops), Soil-water-plant relationships.
Identifiers: Iran, Straw.

Application of nitrogen with or without phosphorus, moisture levels and season have a great effect on yield, growth characteristics and protein content of winter wheat. Variations in moisture under semiarid conditions of southern Iran can drastically change yield patterns of winter wheat (Triticum aestivum L) within the same or over several seasons. An experiment considering effects of spring irrigation and fertility levels on components of yield, plant characteristics and yield of grain and straw of 'Roushan' variety of winter wheat was conducted. The 3-year study showed that grain and straw yields were positively and significantly correlated with levels of irrigation in each crop season, and in combined 3 years, correlations for grain yield to levels of fertilizer were negative and significant. Correlation coefficients showed components of yield to be more affected by season and irrigation level than other factors, thus a fluctuation in moisture level shows a fluctuating yield pattern.

72-73:03F-027
WATER USE BY SUGAR BEETS IN A SEMIARID ENVIRONMENT AS INFLUENCED BY POPULATION AND NITROGEN FERTILIZER,
Moraghan, J. T.
North Dakota State University, Fargo, Department of Soils.
Agronomy Journal, Vol. 64, No. 6, p 759-762, November-December, 1972. 4 fig, 4 tab, 10 ref.

Descriptors: *Water utilization, *Sugar beets, *Semi-arid climates, *Dry farming, *Fertilizers, Nitrogen compounds, Plant populations, Crop production, Consumptive use, Root development, Plant growth regulators, Seasonal, Precipitation (Atmospheric), Water demand, Leaves, Nitrates, Soil-water-plant relationships.
Identifiers: Leaf area index (LAI), Sucrose.

Sugar beets (Beta vulgaris) are deep-rooting crops which seek moisture and are influenced by nitrogen (N) fertilizer. The decrease in the quality of American beets is of concern. The influence of population and N fertilizer on leaf area index (LAI) and on water use by beets under dry land conditions in a semiarid environment is reported, as little is known of beets in these conditions. Growing season was characterized by long periods with little precipitation, where extensive use of stored soil moisture occurred to a depth of at least 183 cm. Populations of 26,400 and 70,700 plants/ha, and N fertilizer rates of 0, 56, 112 and 224 Kg/ha were observed. Higher population and fertilizer treatments increased water use by 9.5 and 3.5 percent, and yield of sucrose by 20 and 15 percent respectively. LAI increased much more markedly by both treatments. Greatest effect of increasing population on water use was most evident in the deepest depths from which soil moisture was utilized. Beets utilized soil nitrate to at least 152 cm. High yields under dry land conditions with limited precipitation was the result of the deep rooting nature of sugar beets and relatively large amount of preplanting available stored soil moisture.

72-73:03F-028
EFFECT OF THE SOIL AND PLANT WATER POTENTIALS ON THE DRY MATTER PRODUCTION OF SNAP BEANS,
Millar, A. A., and Gardner, W. R.
Department of Soils, University Concepcion, Chillan, Chili Concepcion University (Chile).
Agronomy Journal, Vol. 64, No. 5, p 559-562, 1972.

Identifiers: *Soil-water-plant relationships, *Beans, Dry, Growth, Phaseolus vulgaris, Plants, Potentials, Production, Rates, Resistance, Soils, Stomatal, Transpiration.

The dry matter production rate of snap beans (Phaseolus vulgaris L., cv. 'Bush Blue Lake') growing under field conditions on a sandy soil is analyzed during a drying period. Measurements of plant- and soil-water potentials, dry matter accumulation, and stomatal resistance were made as soil-water was depleted, while the transpiration rate were obtained by a model for a loosely structured canopy. The transpiration and dry matter production rates decreased curvilinearly with soil-water potential. When the soil-water potential decreased from -0.28 to -0.40 bar, there was 47% reduction in the dry matter production rate. This is related to the turgor pressure-operated stomatal mechanism. The adaxial stomatal resistances increased at leaf-water potentials lower than -8 bars, which coincided with a rapid decrease in the dry matter production rate. Stomatal closure due to water stress resulted in a greater reduction of growth rate than in transpiration.

72-73:03F-029

EFFECT OF AERIAL ENVIRONMENT AND SOIL WATER POTENTIAL ON THE TRANSPIRATION AND ENERGY STATUS OF WATER IN WHEAT PLANTS,

Yang, S. J., and DeJong, E.
Washington State University, Pullman, Department of Agronomy and Soils.
Agronomy Journal, Vol. 64, No. 5, p 574-578, 1972. Illus.

Identifiers: Aerial environment, Capillary conductivity, *Energy status, Evaporation, Humidity, Soils, Temperature, Texture, *Transpiration, Triticum-aestivum, *Wheat, Wilting, *Soil-water potential.

Thatcher wheat (Triticum aestivum L.) was grown under 4 combinations of air temperature and relative humidity in a loam and a clay soil. The relationship between transpiration rate and soil water potential depended on evaporative demand and soil texture. The decline in the transpiration rate from its maximum commenced at higher soil water potentials under conditions of higher evaporative demand and was more gradual on the clay than on the loam soil, presumably due to the higher capillary conductivity of the former. Permanent wilting occurred at soil water potentials of -20 to -25 bars on the loam soil and at -45 to 50 bars on the clay soil. At these potentials the capillary conductivities of both soils were about equal. Resistance to water flow in the plant decreased with increased temperature, while changes in relative humidity had no consistent effect. The total resistance to water movement in the plant and the soil increased with decreasing soil water potential and decreasing air temperature. The relationship between leaf water potential and relative water content was affected by aerial environment and soil texture.

72-73:03F-030

EFFECT OF MOISTURE STRESS AT DIFFERENT STAGES OF GROWTH: II. CYTOPLASMIC MALE-STERILE CORN,

Vincent, G. B., and Wooley, D. G.
Iowa State University, Davenport, Cooperative Extension Service.
Agronomy Journal, Vol. 64, No. 5, p 599-602, September-October, 1972. 4 fig, 2 tab, 12 ref.

Descriptors: *Moisture stress, *Plant growth, *Corn (Field), *Crop response, *Soil moisture, Seeds, Labor, Drought tolerance, Soil-water-plant relationships, Growth stages, Crop production, Leaves, Water management (Applied), Adaptation, Water demand, Consumptive use, Water conservation.
Identifiers: *Cytoplasmic male-sterile corn, *Hybrids, *Leaf turgor.

Cytoplasmic male-sterile (cms) corn (Zea mays) hybrids are used extensively in recent years by commercial seed producers to reduce labor. This study determines if the greater moisture stress-tolerance of corn plants with male-sterile cytoplasm was due to their ability to extract more moisture from soil and retain it against atmospheric demand. Experiment was conducted on Colo silt loam soil in 1967 at Ames, Iowa to compare effects of moisture stress at different stages of growth on Texas male-sterile cytoplasm corn hybrids and their normal cytoplasm counterparts. Grain yield reduced significantly by imposed moisture stress. Hybrids with cms did not yield differently from normal counterparts, but cms hybrids maintained a higher leaf turgor level when stressed. Equally severe stress intensities were established by withholding irrigation water until a minimum level of 75 percent leaf turgidity was reached. Normal hybrids withstood 1 day of serious stress during a 3-day period, while cms hybrids withstood 3 days of serious stress during a 10-day period before reaching minimum leaf turgidity. The stress-tolerant cms hybrids have significant impact on water management and adaptation of corn plants.

72-73:03F-031

EFFECT OF PLANTING DATE ON WATER-USE AND ITS EFFICIENCY IN DRY LAND GRAIN SORGHUM,

Blum, A.

Volcani Institute of Agricultural Research, Bet-Dagan (Israel), Division of Field Crops.

Agronomy Journal, Vol. 64, No. 6, p 775-778, November-December, 1972. 4 fig, 3 tab, 20 ref.

Descriptors: *Dates, *Water utilization, *Water demand, *Crop production, *Grain sorghum, Planting management, Consumptive use, Efficiencies, Dry farming, Precipitation (Atmospheric), Seasonal, Soil moisture, Water rates, Plant growth, Plant growth regulators, Spring, Water supply, Limiting factors, Vegetation, Leaves, Weight, Emerging vegetation state, Moisture stress, Adaptation, Root development, Evapotranspiration.

Identifiers: *Hybrids, Israel, Soil extraction profiles, Tillering, Leaf diffusion resistance, Heading, Leaf desiccation.

No precipitation occurs in the growing season, and water is provided under dry land conditions by stored soil moisture in many of the grain sorghum (Sorghum bicolor (L.) Moench) growing areas. This research was conducted to appraise the postulation that water regime is the major operative factor responsible for different yield response of dry land grain sorghum. Four grain sorghum hybrids were planted on two spring dates for four consecutive years in Israel under conditions of limited water supply, or preplanting stored soil moisture. Vegetative development, grain yield and soil water extraction profiles were determined to show early planting increased grain yield through increased tillering and greater weight per grain. Early planted sorghum used about half as much water as the late plant, from emergence to 31 days. Early plants were less water stressed as evidenced by lower leaf diffusion resistance prior to heading and smaller reduction in leaf desiccation after heading. Lower water use by early plants was ascribed to lower potential evapotranspiration, smaller leaf desiccation and slower root development. Total amount of water consumed by both time plantings were the same. No differences were noted in terms of hybrid adaption to early planting or water use. Stored soil moisture is necessary for dry land sorghum production.

72-73:03F-032

EFFECTS OF WATER AND HEAT ON SEEDLING EMERGENCE,

Feddes, R. A.

Institute for Land and Water Management Research, Wageningen (Netherlands).

Journal of Hydrology (Amst). Vol. 16, No. 4, p 341-359, 1972. Illus.

Identifiers: Bean, Beet Gardens, Heat, Irrigation, *Moisture, Radish, Rainfall, *Seedling emergence, Soils, Spinach, *Temperature, Water, *Germination.

The combined effect of soil temperature and moisture content on seedling emergence was studied with 4 different kinds of vegetable seeds, radish, spinach, broad bean and garden beet, in field experiments in a clay and a sandy loam profile, both with a shallow and a deep groundwater table. Various sowing dates were applied. The mean daily temperatures of the plots with the higher groundwater tables were 1-2C lower than the temperature of the plots with the deeper groundwater tables. With the same groundwater depth, clay was warmer than sandy loams. The difference in groundwater level play a more important role than the difference in type of profile. The maxima and minima in the top soil were higher and the amplitudes decreased with depth faster in soils which had a deep groundwater table. The decrease was more marked in the clay than in the sandy loam soil. Seeds emerged earlier in sandy loam than in clay. The sandy loam plots with the shallow groundwater table showed the highest emergence rate as well as the highest total emergence percentage. The mean heat sums required for 50% emergence were lower on sandy loam than on clay, and the heat sums of the shallow groundwater plots were lower than those of the deep groundwater plots. The heat sum required for 50% emergence increased sharply below a matric pressure of -0.49 bar (above pF (water holding index 2.7) of the soil. For a fast and adequate seedling emergence both a high temperature and a sufficient moisture content are necessary. By sprinkler irrigation the sowing bed can be kept at the desired moisture content.

72-73:03F-033
ESTIMATING DEEP DRAINAGE BETWEEN IRRIGATIONS,
Miller, D. E., and Aarstad, J. S.
Agricultural Research Service, Prosser, Washington, Soil Science Division.
Soil Science Society of America proceedings, Vol. 36, No. 1, p 124-127, 1972.
Illus.

Identifiers: *Drainage, *Irrigation, Evapotranspiration.

The situation, common in irrigation, in which the water table is deep enough to be ignored and applied water moves downward by drainage and is taken up by plants was studied. When plants are transpiring, soil water content is reduced by both deep drainage and plant extraction. Drainage rates from a wetted depth of soil are related to the total water contained in that depth when there is no plant use. This same relation can be used to estimate drainage following an irrigation when the soil is cropped. However, in a series of irrigations, there is a delay between the end of irrigation and the beginning of drainage, and drainage is overestimated. If reduced irrigation efficiencies can be tolerated, overirrigation can lengthen time between irrigations, especially if evapotranspiration rates are low.

72-73:03F-034
COMPUTER SIMULATION ANALYSIS ON RECLAMATION OF SALT-AFFECTED SOILS IN SAN JOAQUIN VALLEY, CALIFORNIA,
Tanji, K. K.
California University, Davis.
Soil Science Society of America Proceedings, Vol. 36, No. 1, p 127-133,
January-February 1972. 9 fig, 3 tab, 34 ref.

Descriptors: *Saline soils, *Leaching, *Computer models, *Simulation, Sodium, Gypsum, Boron, Land reclamation, Percolation, Field data, California, Bibliographies, Analysis, Drainage effects, Drainage.
Identifiers: *Salt removal, San Joaquin Valley (California), Soluble salts.

A computer land reclamation model was applied to a field leaching study of moderately salt-affected profiles. Leaching was accomplished by ponding 15 cm of water intermittently in 3-m by 3-m basins every 1 to 2 weeks. Computer predictions on the degree of reclamation were compared with measured changes in soluble salts, soluble boron, and the sodium adsorption ratio to soil depths of 274 cm. The differences between computed and measured field data were no more than the horizontal variations found in salt-affected lands in this area and elsewhere. Predicted drainage water quality and a method for computing gypsum requirements of sodium-affected profiles are reported. Computer programming techniques provide a better understanding of the complex salt problem in irrigated lands.

72-73:03F-035
SPRINKLER PRECIPITATION GAGE ERRORS,
Kohl, R. A.
Snake River Conservation Research Center, Kimberly, Idaho.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 264-265, 271, March-April, 1972. 2 fig, 1 tab, 7 ref.
(See 72-73:02G-029)

72-73:03F-036
MATHEMATICAL MODEL OF WATER ADVANCE IN BORDER IRRIGATION,
Bassett, D. L.
Washington State University, Agricultural Engineering Department, Pullman.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 992-995, September-October, 1972. 3 fig, 12 ref.
(See 72-73:04A-008)

72-73:03F-037
SEMI-PORTABLE SHEET METAL FLUME FOR AUTOMATED IRRIGATION,
Uhl, V. W., Jr., and Garton, J. E.
Oklahoma State University, Agricultural Engineering Department, Stillwater.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 256-260, March-April, 1972. 7 fig, 7 ref.
(See 72-73:04A-009)

72-73:03F-038
DEVELOPMENT OF ASPHALT MOISTURE BARRIER EQUIPMENT,
Fischer, R. C.
International Harvester Company, Hinsdale, Illinois.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 630-631, July-August, 1972. 2 fig, 6 ref.
(See 72-73:02G-033)

72-73:03F-039
IRRIGATION CANAL SYSTEM CAPACITY DESIGN CRITERIA,
Earles, J. D.
Harza Engineering Company, Chicago, Illinois.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR3, Proceedings paper No. 9973, p 227-235, September 1973. 1 fig, 2 tab, 4 ref.

Descriptors: *Canals, *Design, *Irrigation practices, *Land tenure, *Land use, Estimating, *Evapotranspiration, Irrigation systems, Irrigation water, Water requirements, Water delivery, Irrigation efficiency, Farms.
Identifiers: Capacity criteria, *Cropping patterns, *Iran (Khuzestan), Crop yield.

Estimates of peak period evapotranspiration requirements for projected cropping are used to determine the minimum capacities necessary for main and secondary canals. In irrigation project design, the peak period of consumptive use is the period during which the weighted average daily rate of evapotranspiration of the various crops grown in the project areas is at a maximum. Different crops may have their peak rates at different times. To provide water when and where needed, at minimum cost, a detailed evaluation is necessary to prevent over- and under-design of canals. Land tenure after project construction is an important factor in determining the required capacity of project irrigation canals. An example of this factor is demonstrated in the Khuzestan area of Iran which has undergone a recent change in Government land tenure policy. The policy of subdividing project lands into small parcels for lease or sale to farmers was changed to permit an agribusiness lease-type of operation during initial project development. This change caused an increase in the projected summer cropping intensities, resulting in higher peak irrigation water requirements. To deliver the additional water, canal capacity increases of up to 50 percent was required over the original design.

72-73:03F-040
SOME EVIDENCE OF STOMATAL RESTRICTION OF EVAPORATION FROM WELL-WATERED PLANT CANOPIES,
Shepherd, W.
Commonwealth Scientific and Industrial Research Organization, Aspendale, Victoria, Australia.
Water Resources Research, Vol. 8, No. 4, p 1092-1095, August, 1972. 2 tab, 4 fig, 10 ref.
(See 72-73:02D-021)

72-73:03F-041
OPERATION AND MAINTENANCE OF IRRIGATION AND DRAINAGE SYSTEMS: SECTION III. - OPERATION,
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR3, p 237-338, September, 1973. 36 fig, 28 ref.
(See 72-73:04A-027)

72-73:03F-042
UNIFORM IRRIGATION WITH LOW-PRESSURE TRICKLE SYSTEMS,
Myers, L. E., and Bucks, D. A.
United States Water Conservation Laboratory, Phoenix, Arizona.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR3, p 341-346, September, 1972. 2 fig, 7 ref.

Descriptors: *Irrigation systems, *Application systems, *Orifices, *Irrigation practices, Pipe flow, Water distribution (applied), Distribution systems, Irrigation design, Irrigation engineering, Irrigation, Irrigation efficiency.

Application uniformity from low-pressure trickle irrigation systems can be greatly improved by varying emitter sizes to compensate for friction-induced pressure changes in the lateral pipe. Low-pressure systems using simple emitter sizes suffer from nonuniform emitter discharge because friction-induced pressure changes are a large percentage of total pressure. High-pressure trickle systems alleviate this problem by using high head loss emitters. Low-pressure systems, using simple emitters, can have several advantages over high-pressure systems in reduced manufacturing and operating costs, larger emitter orifices to reduce clogging, and simpler flow control devices. Comparable application uniformity can be obtained by varying emitter sizes in the low-pressure systems. Procedures for designing low-pressure multiple-emitter size trickle systems by computer or by a simplified computation and graphic method were developed.

72-73:03F-043
PLANT NUTRIENT CONCENTRATIONS IN RUNOFF FROM FERTILIZED CULTIVATED EROSION PLOTS AND PRAIRIE IN EASTERN SOUTH DAKOTA,
White, E. M., and Williamson, E. J.
South Dakota State University, Brookings.
Journal of Environmental Quality, Vol. 2, No. 4, p 453-455, October-December, 1973. 3 tab, 6 ref.
(See 72-73:05B-056)

72-73:03F-044
AGRICULTURAL CHEMICALS IN SURFACE RUNOFF, GROUND WATER, AND SOIL: I. ENDRIN,
Willis, G. H., and Hamilton, R. A.
United States Department of Agriculture, Baton Rouge, Louisiana.
Journal of Environmental Quality, Vol. 2, No. 4, p 463-466, October-December, 1973. 4 tab, 11 ref.
(See 72-73:05B-062)

72-73:03F-045
MINIMIZING NITRATE SEEPAGE FROM THE HULA VALLEY INTO LAKE KINNERET (SEA OF GALILEE): I. ENHANCEMENT OF NITRATE REDUCTION BY SPRINKLING AND FLOODING,
Raven, A., and Avnimelech, Y.
Israel Institute of Technology, Haifa.
Journal of Environmental Quality, Vol. 2, No. 4, p 455-458, October-December, 1973. 3 fig, 4 tab, 11 ref.
(See 72-73:05B-063)

72-73:03F-046
FUNCTIONS TO PREDICT EFFECTS OF CROP WATER DEFICITS,
Stewart, J. I., and Hagan, R. M.
California University, Water Science and Engineering Department, Davis.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR4, p 421-439, December, 1973. 4 fig, 38 ref.

Descriptors: *Agriculture, *Climates, Crop production, Droughts, Economics, Efficiencies, Evapotranspiration, Irrigation, Management, Planning, Profit, Research and development, Soil water, Water, Water resources.

A well-advanced research program is aimed at quantitative prediction of relations between principal crops and water. Goals are to: (1) Estimate functional relations between crop yield (Y) and water at all water supply levels; water being defined as seasonal depths of both evapotranspiration (ET) and irrigation (IRR); and (2) optimize water management by maximizing profit or water use efficiency or other objective. Davis, California, field and lysimeter studies with corn show: (1) The Y versus ET function is linear, provided unavoidable ET deficits from limited irrigation water coincide with those crop growth stages that influence yield the least; and (2) the Y versus IRR function is convex, reflecting decreasing irrigation efficiency (percentage of IRR utilized in ET) as actual crop ET approaches fulfillment of maximum requirements. When IRR equals zero the two functions become one, and ET derives entirely from stored soil water and rainfall.

72-73:03F-047

THEORETICAL IRRIGATION TAILWATER VOLUMES,

Wilke, O. C.
Texas A & M University, Agricultural Experiment Station, Lubbock.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR3, p 415-420, September, 1973. 1 fig.

Descriptors: *Irrigation, *Agricultural runoff, *Irrigation practices, Irrigation design, Tailwater, Furrow irrigation, Irrigation systems, Surface runoff.

A volume balance theory and graphical relationships for predicting irrigation tailwater volumes are presented. An equation is derived for determining tailwater pumping rates for the case where tailwater is continuously recirculated. Dimensionless graphs illustrate the effects of the time period of runoff on both runoff volumes and irrigation uniformity. Use of this information could improve the management of furrow irrigation systems and also aid in the design of tailwater pits, pumps, and return pipelines.

72-73:03F-048

PHYSICAL MODEL STUDY OF BORDER-STRIP IRRIGATION,

Jobling, G. A., and Turner, A. K.
Engineering, Irrigation, and Water Supply Commission, Queensland, Australia.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR4, p 493-510, December, 1973. 14 fig, 1 tab, 20 ref.
(See 72-73:04A-028)

72-73:03F-049

WHEAT RESPONSE TO DIFFERENT SOIL WATER-AERATION CONDITIONS,

Anaya, M. G., and Stolzy, L. H.
California University, Riverside, Department of Soil Science and Agricultural Engineering.
Soil Science Society of America Proceedings, Vol. 36, No. 3, p 485-489, 1972. Illus.

Identifiers: *Aeration, Grain oxygen, Protein, Soils, Triticum-Aestivum-M, *Wheat-M, *Soil water.

A graphical yield surface was constructed for wheat (Triticum aestivum L.) grown on Yolo silt loam with 13 different soil water-aeration combinations. The experiment was conducted in a growth chamber under controlled environmental conditions. O2 over the soil surface was maintained at different percent O2 concentrations 0.9-21%. Various soil water regimes were obtained by irrigation at different soil suctions 8-99 centibars (cbars). The highest grain yields were obtained in 2 treatments, one of 9.6% O2 watered at a soil suction of 15 cbars, and another treatment of 4.3% watered at cbars. The lowest production was in the treatment of 0.9% O2 watered at 99 cbars, and the difference between the highest and lowest yields was 347%. From the data, the regression equation for grain yield was Y ± 15.94 - 0.1324 X1 + 3.1813 X2 ± 0.1297X22, where Y ± grain yield in g/pot, X1 ± soil suction in cbars, and X2 ± percent O2. The maximum predicted yield calculated from the equation is at a level of 12.0% of O2 irrigated at a soil suction of 8 cbars. However, the maximum production recorded was obtained at 9.6% O2. There was a high correlation coefficient (0.94) between water consumption and grain production. An inverse relationship existed between grain yield and protein content. The highest level of grain protein content (22.6%) was obtained in the lowest producing treatment, while the lowest level of grain protein content (16.5%) occurred in the highest producing treatment. The difference in grain protein content between treatments was 37%.

72-73:03F-050
CULTURAL PRACTICES FOR IRRIGATED WINTER WHEAT PRODUCTION,
Unger, P. W., Allen, R. R., and Parker, J. J.
United States Department of Agriculture, Bushland, Texas.
Soil Science Society of America Proceedings, Vol. 37, No. 3, p 437-442, May-June, 1973. 5 tab, 21 ref.
(See 72-73:02G-129)

72-73:03F-051
SIDE ROLL SPRINKLERS,
Miller, M.
Miller (Marion) and Associates, Incorporated, Colorado Springs, Colorado.
Irrigation Age, Vol. 7, No. 6, p 24-25, 62, 65, January 1973. 3 photo, 1 tab.

Descriptors: *Irrigation, *Sprinkler irrigation, *Irrigation systems, Irrigation operation and maintenance, Irrigation efficiency, Irrigation practices, Surface irrigation, Water distribution (Applied), Aluminum, Farm management, Pipes, Agricultural engineering.

The side roll sprinkler is the first successful attempt to mechanize the conventional hand move system. This system can be used on any size rectangular-shaped farm where low to medium height crops are grown. Development of the system and the present approach to the wheel and coupler attachments are described. In 90% of the systems, the wheels are connected to the middle of a pipe length and a coupler, incorporating a riser and drain, connects the pipe lengths. Components used in the present side roll system are: different sizes of aluminum pipes, couplers, wheels, power movers, self-alining risers, and drains. From the standpoint of water distribution, the most popular system is 1/4 mi long, with a sprinkler every length of pipe. Factors to be considered when purchasing a side roll system and recommended operating procedures are presented.

72-73:03F-052
FARMING CIRCLES,
Miles, D. L.
Colorado State University, Fort Collins.
Irrigation Age, Vol. 7, No. 6, p 20-21, 48, 53, 56, January 1973. 1 photo.

Descriptors: *Irrigation, *Sprinkler irrigation, Irrigation operation and maintenance, *Irrigation efficiency, Irrigation practices, Irrigation systems, Surface irrigation, Water distribution (Applied), Agricultural engineering, Farm management, Water requirements, Crop response, Planting management.
Identifiers: Irrigation requirement, Cropping patterns.

Circular farming with elimination of end guns, running wheels on ridges, and smoothing the surfaces are procedures that increase the potential profit of center-pivot irrigation farming. For a typical 132-acre system, the elimination of end guns will reduce the irrigated acreage to 122 acres. However, the uniformity of irrigation will usually result in more total yield than from the

132 acres without having to till, plant, fertilize, irrigate, and harvest the additional 10 acres. Running the wheels on a slight ridge reduces rutting and traction problems as the water will run from the tracks. Recommendations that ridges be built around the field and circular planting be used for a more efficient field operation are presented. Smoothing small land undulations and planting parallel to the wheel tracks to eliminate water trapping will result in a more uniform infiltration. Preirrigation, a very important farming practice, when used to the full depth of the root zone, helps to break up surface crusts at the time of planting, and to condition the soil to accept irrigation water. Operating pressure of 85 to 90 psi is recommended at the pivot for common sprinkler spacings of about 30 ft. High operating pressures produce a more constant application of water which can be absorbed easily by the soil.

72-73:03F-053
SHOULD I IRRIGATE ONLY EVERY OTHER ROW,
Milligan, T.
Irrigation Age, Vol. 7, No. 7, p 16-18, March, 1973. 1 fig, 2 tab.

Descriptors: *Irrigation practices, *Furrow irrigation, Surface irrigation, Water conservation, Crop response, Crop production.

Tests on irrigating every other furrow have been conducted at the University of Nebraska. The field getting water applied down every furrow was irrigated six times, used 14.9 inches of irrigation water to go with the 11.8 inches of rain during the growing season. That plot made 170 bushels per acre. Where the same every other furrow was irrigated, the same number of times, 10.7 inches of water was applied and 161 bushels were harvested per acre. The every other furrow (alternated) used 10.5 inches of irrigation water and yielded 163 bushels an acre. Tables showing results of further tests are presented.

72-73:03F-054
TAILWATER,
Milligan, T.
Irrigation Age, Vol. 7, No. 5, p 6-7, December, 1972. 4 fig.

Descriptors: *Runoff, *Tailwater, Return flow, Irrigation practices, Furrow irrigation, Water conservation, Soil conservation, Farm ponds.
Identifiers: Reuse systems.

Economics of tailwater reuse on the Texas plains are discussed. Surveys show that much of the water required for adequate furrow irrigation is wasted off the end of the fields. When 3 to 4 wells contributed to one reuse system it was found that the system will return as much water as one well will produce. Thus producing a water savings of 25-30%. Tips on the construction and operation of the reuse system are presented.

72-73:03F-055
REDUCED TILLAGE FARMING: SAVES WATER AND DOLLARS,
Irrigation Age, Vol. 7, No. 3, p 12-14, October, 1972. 2 fig.

Descriptors: *Cultivation, Farm management, Soil management, Conservation, Crop production, Land management, Crop response, Planting management, Soil

conservation.
Identifiers: Minimum tillage.

Minimum tillage farming, once thought only useful in dryland areas, is now becoming popular under a wide variety of irrigation systems. The main advantages are : moisture conservation,lower production cost, higher profits, reduced erosion, better seedling survival, improved soil structure, increased land opportunity, wildlife habitat, and lower labor requirements.

72-73:03F-056
SOLID SET SPRINKLER IRRIGATION,
Robinson, F. E.
California University, El Centro, Imperial Valley Field Station.
Agricultural Engineering, Vol. 53, No. 4, p 15-16, April 1972. 4 fig, 5 tab.

Descriptors: *Sprinkler irrigation, *Irrigation practices, Crop production, Arid climates, *California, Spatial distribution, *Vegetable crops, Salt balance.
Identifiers: *Imperial Velley.

In the arid Southwest where irrigation is a necessity, large increases in Long Imperator carrots, Climax lettuce, Calicel lettuce, Scarlet Globe radishes, and Yellow Granex onions have been made possible by sprinkler irrigating plants grown in flat beds using grid spacings with two inch variance ranging from 10 x 10 to 24 x 24. Sprinkler irrigation is important in the arid Southwest to prevent salt accumulation on the seed row surface until the seeds emerge. After emergence, the seedlings are then furrow irrigated, allowing the portable solid set sprinklers to be used in another field. Research indicates that if all irrigation were done by sprinklers, the furrows could be eliminated. Plants are being grown in various grid patterns to identify those that produce the highest marketable yields at the highest degree of uniformity.

72-73:03F-057
AUTOMATED IRRIGATION IS HERE,
Hagood, M. A.
Washington State University, Prosser, Cooperative Extension Service.
Agricultural Engineering, Vol. 53, No. 10, p 16-18, October 1972. 2 tab, 7 ref.

Descriptors: *Sprinkler irrigation, *Trickle irrigation, *Irrigation operation and maintenance, Irrigation systems, Furrow irrigation, Irrigation efficiency, Irrigation engineering, Water management (Applied), Automation, Distribution systems, Costs, Surface irrigation.

Displacement of rural Americans is an inevitable consequence of irrigation technology that will continue to displace inefficient equipment and labor; however, this new technology will add to the total growth, efficiency, and competitiveness of irrigated agriculture. Low-skilled labor is now being replaced with better trained, better paid, and more dependable managerial personnel. New irrigation systems make possible development of previously considered non-irrigable land. Trickle irrigation allows use of low quality water, as sprinkler irrigation allows waterflow management which can significantly affect sediment concentration, nutrient content, and overall water quality of return flows. Automation of surface systems in open channels maintains uniform water levels, in addition to a 30 percent savings in water use. The costs of owning and operating selected sprinkler systems are presented and as the beneficial aspects of type and automation level of various systems are discussed.

72-73:03F-058
YIELD OF FLUE-CURED TOBACCO AND LEVELS OF SOIL OXYGEN IN LYSIMETERS WITH DIFFERENT WATER TABLE DEPTHS,
Campbell, R. B., and Seaborn, G. T.
Agricultural Research Service, Florence, South Carolina, Soil and Water Conservation Research Division.
Agronomy Journal, Vol. 64, No. 6, p 730-733, 1972. Illus.

Identifiers: Alkaloids, *Carbon dioxide, Growth, Lysimeters, Nicotiana-Tabacum, *Oxygen, Root, Shoot, *Soil aeration, Sugars, *Tobacco yield, Water tables.

Flue-cured tobacco (Nicotiana tabacum L.) was grown in lysimeters with static water-table levels at 30, 45, 60 and 90 cm below the soil surface to more clearly define the level at which a favorable balance between soil aeration and water supply is attained. The O2 and CO2 content of the soil air was determined periodically at various depths. Water-table treatment effects were evaluated in terms of root and shoot growth, yield and quality of tobacco. Dry leaf yeilds for the 90-, 60- and 45-cm water-table treatments were all significantly (P greater than or equal to 0.05) greater than that for the 30-cm treatment. Yields for the 60- and 90-cm water-table levels were larger, but not significantly (P greater than or equal to 0.05) larger than the 45-cm treatment. The yield difference between the 60- and 90-cm treatments was not significant (P greater than or equal to 0.05). Roots of tobacco recovered from soil above the 60- and 90-cm water tables weighed only 10% more than roots recovered from soil above the 30-cm water table. Average CO2 and O2 gradients in the soil above the water table were nearly equal but of opposite sign. Soil environmental conditions imposed by the 60-cm water-table treatment provided the most favorable balance between aeration and water supply for tobacco.

72-73:03F-059
INFLUENCE OF IRRIGATION ON THE YIELD AND PERSISTENCE OF FORAGE LEGUMES,
Wahab, H. A., and Chamblee, D. S.
Ministry of Agriculture and Lands, Kuala Lumpur (Malaysia), Division of Agriculture.
Agronomy Journal, Vol. 64, No. 6, p 713-716, 1972.

Identifiers: Coronilla-Varia, Disease, *Forage legumes, *Irrigation, Legumes, Medicago-Sativa, Trifolium-Repens, *Crop yield, Alfalfa, Clover, Crownvetch, Soil moisture.

The effect of irrigation on the yield of 3 alfalfa (Medicago sativa L.) cultivars, crownvetch (Coronilla varia L.) and ladino clover (Trifolium repens L.) was studied in the field over a 2-year period. The nonirrigated plants received natural precipitation, whereas the irrigated legumes were supplied with supplemental water in addition to the rainfall whenever soil moisture was depleted to approximately 50% of the available water-holding capacity. At the first harvest after irrigation in the first year, superior growth of all legumes was obtained by the use of supplemental water. The benefits of irrigation to some species and cultivars ended at this point. Yields of alfalfa were sharply reduced in mid- and late-summer of the second year as a result of irrigation. Irrigation of the 3 alfalfa varieties resulted in an overall decrease in yield of 76% at the last harvest. The alfalfa varieties responded differentially to irrigation. Most of the stand of crownvetch was lost following the first cut on the irrigated plots. In contrast to other legumes, irrigation increased the yields of ladino clover by approximately 19%. Severe infestation by several diseases was probably a primary factor in the severe stand loss and low yields of alfalfa and crownvetch under irrigation. Excessive soil moisture due to precipitation soon after irrigation also possibly contributed to the loss of alfalfa stands.

72-73:03F-060
INFLUENCE OF WATER MANAGEMENT THROUGH IRRIGATION AND A SUBSURFACE ASPHALT LAYER ON SEASONAL GROWTH AND NUTRIENT UPTAKE OF CORN,
Robertson, W. K., Hammond, L. C., Saxena, G. K., and Lundy, H. W.
Florida University, Soil Science Department, Gainesville.
Agronomy Journal, Vol. 65, No. 6, p 866-868, November-December, 1973. 3 fig, 3 tab, 8 ref.

Descriptors: *Irrigation, *Drainage, *Deep percolation, Sand, Fertility, Leaching, Water loss, Asphalt, Water management (applied).

During the past five years improved water management of droughty sandy soils has been attained by constructing, at a depth of 60 cm, a continuous layer of asphalt about 0.3 cm thick. Plots on a Typic Quartzipsamment were treated in 1967 and used in 1970 and 1971 to measure seasonal growth and nutrient uptake of corn in response to the following water management treatments: check, irrigation, asphalt layer, and irrigation with asphalt layer. Responses to fertilizer rate and plant population were also obtained. The asphalt layer increased corn fodder yields above the check and irrigation treatments during the first 11 weeks when moisture stress was moderate. At this time an 11-day drought caused a severe water stress on the check and asphalt layer treatments. The seasonal response of corn to water management showed that the asphalt layer system was effective in increasing water use efficiency in well-drained sandy soils.

72-73:03F-061
EFFECT OF GRAVEL MULCH ON CROP YIELDS,
Fairbourn, M. L.
United States Department of Agriculture, Agricultural Research Service, Fort Collins, Colorado.
Agronomy Journal, Vol. 65, No. 6, p 925-928, November-December, 1973. 3 fig, 3 tab, 12 ref.

Descriptors: *Mulching, *Corn, *Gravels, Soil water, Evaporation control, Soil temperature, Water conservation.

A study was established to determine if this mulch material might be used to promote increased crop yields from the precipitation of semi-arid regions. Treatments of gravel mulch, cornstalk mulch, and a control of bare soil were used in both laboratory and field experiments to observe their effect on soil water, soil temperature, and plant response. Evaporation of soil water was less and soil temperatures were higher under gravel mulch as compared with a bare soil surface. Increased crop yield on the gravel-mulch treatment appeared to be due to an interaction of more soil water and higher soil temperature. Bare soil strips for crop rows and annual regeneration of the gravel mulch were necessary management practices to permit both crop production and maintenance of an effective mulch. The study has indicated that gravel mulch not only promotes increased crop yields but also has a potential for mechanized application and maintenance.

72-73:03F-062
PIMA COTTON LINT YIELD AS INFLUENCED BY IRRIGATION SCHEDULE, CULTIVAR AND ALTITUDE,
Kittock, D. L.
United States Department of Agriculture, Agricultural Research Service, Phoenix, Arizona.
Agronomy Journal, Vol. 65, No. 3, p 498-501, May-June, 1973. 4 fig, 2 tab, 9 ref.

Descriptors: *Irrigation, *Irrigation practices, *Crop response, Cotton, Water conservation, Yield equations.

Development of heat tolerant cultivars of American Pima cotton made it desirable to re-evaluate irrigation practices for hot climates. To accomplish this, two cultivars and one experimental strain were tested over a period of 6 years at two altitudes and under several irrigation regimes. There were three basic irrigation regimes and several modifications of them. The regimes were: wet, irrigate every 7 to 12 days; medium, 14 to 17 days; and dry, 21 to 28 days. Individual irrigations were added in amounts necessary to refill the soil profile. At high altitude, the heat tolerant cultivar, 'Pima S-4', did not differ in water requirement from the non-heat tolerant cultivar, 'Pima S-3'. Both cultivars obtained maximum lint production with a total of 80 cm of water or five post-emergence irrigations. At low altitude, Pima S-4 yielded higher and required more water than Pima S-3.

72-73:03F-063
CROP RESPONSE TO TRICKLE AND SUBSURFACE IRRIGATION,
Hiler, E. A., and Howell, T. A.
Texas A & M University, College Station.
Paper 72-744, 1972 Annual Meeting American Society of Agricultural Engineers, Chicago, Illinois, December 1972. 22 p, 6 fig, 3 tab, 18 ref.

Descriptors: *Crop response, *Irrigation efficiency, *Subsurface irrigation, *Trickle irrigation, Consumptive use, Evapotranspiration, Growth rates, Lysimeters, Irrigation practices, Irrigation systems, Irrigation water, Mist irrigation, Wind velocity, Moisture content, Sorghum, Surface irrigation, Bibliographies, Crop production.

An investigation was conducted to compare wateruse efficiencies using different irrigation methods, and to evaluate effects of reduced irrigation amounts on yields using trickle irrigation. Grain sorghum was grown during 1971-72 in a field lysimeter installation where complete control of the soil water could be maintained Irrigation treatments included subsurface, trickle, subsurface plus mist, trickle plus mist, and surface. Water measurements were made to determine irrigation amount, storage depletion, and drainage amount, so that total crop water use could be determined. Trickle and mist treatment resulted in the highest water efficiencies. The increase in water-use efficiency based on total water use was 42% for trickle treatment compared to surface treatment. Grain sorghum growth as indicated by crop height and leaf area index was greater for all 1971 intensive treatments than for the surface treatment. Comparison of 3 levels of trickle irrigation amounts in 1972 indicates that water-use efficiency increased by 50% with sparing trickle applications.

72-73:03F-064
SOIL MOISTURE EXTRACTION AND IRRIGATION DESIGN REQUIREMENTS FOR CORN,
Fischbach, P. E., and Somerhalder, B. R.
Nebraska University, Lincoln.
Paper 72-770, 1972 Annual Meeting American Society of Agricultural Engineers,
Chicago, Illinois, December 1972. 15 p, 2 fig, 5 tab, 7 ref.

Descriptors: *Water requirements, *Corn (Field), *Irrigation design, *Sprinkler irrigation, Soil moisture, Root zone, Moisture content, Soil-water-plant relationships, Irrigation systems, Automatic control, Design criteria, Rainfall, On-site investigations, Consumptive use, Crop production.
Identifiers: Moisture sensors, Silty loams.

With today's automated equipment, irrigation can be a matter of pressing a button to place a system into operation. However, water must be efficiently applied and rainfall effectively utilized to minimize water waste and to produce high crop yields. To determine the amount of water required to produce the highest corn yield, in 1971-72, field studies were conducted at the University of Nebraska Field Laboratory. Irrigation frequencies of 1.5, 3.0, 3.5, and 7 days applying water in the amounts of 0.30, 0.24, 0.15, and 0.10 in./day design criteria equivalent were studied on Sharpsburg silty clay loam soil. Soil moisture was at field capacity to a depth of 5 ft when corn was planted on all treatments. Soil moisture extraction patterns were monitored on corn for each of the different frequencies and amounts of water applied on each treatment. Design criteria for irrigation system capacity were calculated to apply the different amounts of water. Irrigation frequencies studied did not affect corn yields or change soil moisture extraction patterns. Yields averaged 8 bushels/acre greater on treatments where 0.15 in./day design criteria equivalent was applied, regardless of irrigation frequency.

72-73:03F-065
WATER REQUIREMENTS FOR OPTIMUM CROP YIELD,
Shih, S. F., Sneed, R. E., and Sowell, R. S.
Corps of Engineers, West Palm Beach, Florida.
Paper 72-773, 1972 Annual Meeting American Society of Agricultural Engineers,
Chicago, Illinois, December 1972. 16 p, 6 tab, 5 ref.

Descriptors: *Agronomy, *Water requirements, *Crops, Mathematical models, Water utilization, Root systems, Time, Irrigation efficiency, Computer programs, Consumptive use, Crop response, Soil-water-plant relationships, Fourier analysis, Growth stages, Growth rates, Root development, Soils, Plant growth, Crop production.
Identifiers: Coefficients.

Two mathematical models developed to provide input for determining agricultural water requirements are presented. One determines the water requirement of a plant as a function of time after planting; the other determines the rooting depth as a function of time from date of planting and soil type. Both models are formulated to make daily calculations from planting date through maturity. Computer programs were developed to determine coefficients of the equations presented. With these coefficients, the model was then used to predict water use and rooting depth of plants as a function of time during the growing season. Predicted water use agreed closely with observed data for selected crops grown in North Carolina. Applications of the water use model and the root depth model are tabulated. With the tabulated data and rainfall data, the water-holding capacity of the soil will be used to determine irrigation water requirements for each soil/crop combination in any of the 60 time intervals during the year.

72-73:03F-066
FIELD LEACHING BY SPRINKLER AND SURFACE IRRIGATION DURING A CROP SEASON,
Hermsmeier, L. F., and Kaddah, M. T.
Agricultural Research Service, Brawley, California.
Paper 72-723, 1972 Winter Meet American Society of Agricultural Engineers, Chicago, Illinois, December 1972. 20 p, 4 fig, 3 tab.

Descriptors: *Leaching, *Irrigation, *Sprinkler irrigation, *Surface irrigation, *Salt balance, Drainage, Irrigation effects, Application methods, Subsurface drainage, Soil management, Irrigation efficiency, Crop production, Barley, Salinity, Saline soils, *California, On-site tests, Land reclamation, Rates of Application.
Identifiers: *Imperial Valley (California), Salt removal.

Several major disadvantages of leaching a field by ponding water led to considering sprinklers as an alternative. Laboratory tests indicated that leaching by sprinkler irrigation may not only provide more efficient water use, but also save time, since when soil is not saturated, simultaneous leaching and crop production can occur. In Imperial Valley, California, a field experiment was conducted to determine: (1) the relative leaching effectiveness of sprinkling and surface irrigation on barley, and (2) effects of ponding on crop growth and yield. Results of leaching during 2 barley growing seasons indicated that applying excess irrigation water to a winter barley crop can effectively leach salt from the soil, while obtaining high crop yield. Salt removal improved slightly between drains in the top foot of soil when sprinklers were used, but no improvement was noted at a depth of 5 ft. Surface irrigation resulted in increased leaching and gave higher barley yields than sprinkler irrigation. Application of up to 30% excess water with surface irrigation and 67% excess water with sprinklers did not adversely affect yields.

72-73:03F-067
DETERMINING IRRIGATION POTENTIAL - A COMPUTER MODEL,
Nimmer, G. L., and Bubenzer, G. D.
Paper 72-726, 1972 Winter Meeting American Society of Agricultural Engineers, Chicago, Illinois, December 1972. 15 p, 2 fig, 1 tab, 19 ref.

Descriptors: *Water requirements, *Water distribution (Applied), Computer models, Irrigation, Irrigation efficiency, Irrigation effects, Irrigation programs, Irrigation systems, Soils, Water supply, Crops, Management, Evapotranspiration, Bibliographies, Climate, Wisconsin, Soil properties, Agronomy, Planning, Data storage and retrieval.
Identifiers: *Irrigation requirements.

A computer model was developed to provide irrigators with the irrigation requirements for a crop-soil-management system. In the state of Wisconsin, a complete data bank of irrigation parameters and a method of data retrieval were developed for crops, soils, climate, and water supply. Data bank components discussed are: (1) evapotranspiration rates, (2) crop coefficients, (3) soil characteristics, (4) precipitation, and (5) ground-water supply. Output from the computer program may be divided into 3 sections: (1) input data in both original and coded form, and information from the data storage bank related to input data; (2) results obtained from the water balance, such as weekly values of crop coefficients, evapotranspiration, and total and effective precipitation; and (3) summary of irrigation design parameters used throughout the program. Analysis of preliminary tests indicate general agreement with observed irrigation requirements on sandy soils. Little data are available for comparisons on organic and medium textured soils in Wisconsin; however, results obtained appear to agree with current irrigation practices on these soils.

72-73:03F-068
REUSE OF SURFACE RUNOFF FROM FURROW IRRIGATION,
Pope, D. L., and Barefoot, A. D.
Oklahoma State University, Stillwater, Department of Agricultural Engineering.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 6, p 1088-1091, November-December, 1973. 4 fig, 3 tab, 6 ref.

Descriptors: *Furrow irrigation, *Surface runoff, *Water reuse, Agricultural runoff, *Water conservation, Costs, Pumps, *Oklahoma.
Identifiers: Reuse systems, Storage pit.

Six irrigated fields in the Oklahoma Panhandle were instrumented to determine the amount and time distribution of surface runoff from furrow irrigation. Type H flumes with water level recorders were used to obtain a continuous permanent record of the runoff. The volume of runoff was calculated as a percentage of the volume of water applied for the individual sets and each series of irrigation sets. The variation in runoff percent of the individual sets was analyzed. The characteristics of the time distribution of the runoff from the irrigation sets were defined and used in the design of reuse systems. The runoff percentages from the individual irrigation sets were found to be distributed as a log-normal relationship with a different mean and standard deviation for each field. Reuse systems can be designed with either cycling or continuously operated pumps. Cyclic pumping could be used to accomplish cut-back irrigation. A system with a continuously operated pump requires a smaller pump and pipe size and would have a lower fixed cost. The total annual cost of installing and operating reuse systems is justified for five of the six fields instrumented.

72-73:03F-069
HYDRAULICS AND UNIFORMITY FOR DRIP IRRIGATION,
Wu, I. P., and Gitlin, H. M.
Hawaii University, Honolulu.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR2, p 157-168, June, 1973. 7 fig, 7 ref.
(See 72-73:04A-073)

72-73:03F-070
CHEMICAL METHOD OF PREVENTING LOSS OF INDUSTRIAL AND FRESH WATERS FROM PONDS, LAKES AND CANALS,
Rosene, R. V., and Parks, C. F.
Dow Chemical Company, Dowell Division.
Water Resources Bulletin, Vol. 9, No. 4, p 717-722, August, 1973. 2 fig, 5 ref.
(See 72-73:03E-001)

72-73:03F-071
HOW MUCH WATER FOR THIS IRRIGATION,
Davis, C. H.
Irrigation Age, Vol. 6, No. 8, p 20, 22, 26, March, 1972. 2 fig, 1 tab.

Descriptors: *Irrigation practices, *Irrigation programs, Soil moisture, Crop response, Irrigation systems, Irrigation water, Stress.

A non-technical method for estimating the amount of water required for a given irrigation is presented. The method is based on estimates of the water holding capacity of a soil according to the basic soil texture. Soil moisture content is determined by the feel of the soil or by electronic moisture meters.

72-73:03F-072
TIME IT RIGHT,
Hiler, E. A.
Texas A & M University, Agricultural Engineering Department.
Irrigation Age, Vol. 6, No. 10, p 10-14, 16, May, 1972. 1 fig, 4 tab.

Descriptors: *Irrigation practices, *Irrigation programs, Soil moisture, Crop response, Irrigation systems, Stress.

Proper irrigation scheduling becomes increasingly important when available water supplies are short and/or costly. With proper irrigation scheduling, improved crop yields can be obtained and, often more importantly, water-use efficiencies can be increased. Both timing and amount of irrigation affect water-use efficiency; however, research has shown timing has the greatest effect because at critical growth stages, excessive crop water deficit can irreversibly reduce the potential yield and quality of the crop. A concept which is useful in optimizing irrigation timing is stress day index (SDI). The purposes of this article are to discuss various methods for irrigation timing, to present the SDI concept, to show how this concept is utilized for timing irrigations, and to present experimental results comparing the SDI concept with other irrigation timing methods.

72-73:03F-073
GROW WHEAT AND GRAIN SORGHUM WITH LESS WATER,
Irrigation Age, Vol. 6, No. 11, p 7-10, June, 1972.

Descriptors: *Irrigation practices, *Irrigation programs, Soil moisture, Crop response, Irrigation systems, Wheat, Grain sorghum.

Methods for obtaining maximum yield from limited irrigation water are discussed for wheat and milo. The article is a brief summary of work performed at the Southwestern Great Plains Research Center in Bushland, Texas. Surprisingly good yields from very limited water supplies have been demonstrated.

Section XVIII

WATER QUANTITY MANAGEMENT AND CONTROL

CONTROL OF WATER ON THE SURFACE (Group 04A)

72-73:04A-001
PARALLEL DRAINS FROM THE LAPLACE STANDPOINT,
Glover, R. E.
Colorado State University, Fort Collins, Department of Civil Engineering.
Water Resources Bulletin, Vol. 8, No. 1, p 50-54, February 1972. 1 fig, 2 tab, 4 ref.

Descriptors: *Drawdown, *Drainage systems, *Tiles, *Dupuit-Forchheimer theory, *Laplaces equation, Groundwater movement, Transmissivity, Permeability, Drains, Saturated flow, Unsaturated flow, Water table.

To keep the water table below the root zone of crops, drains are often installed in parallel lines at depths and spacings adapted to the needs of the area. Formulas used for determining drain spacings are generally based upon Dupuit-Forchheimer concepts. These developments postulate a saturated, permeable aquifer underlying the irrigated area and an impermeable barrier underlying the aquifer. If variations of transmissivity due to variations of water-table level are taken into account the second order differential equation obtained is nonlinear. An alternative approach is based upon a requirement that there can be no accumulation of water in any elementary cubical volume located in the zone of complete saturation below the water table. A Laplace-type differential equation is obtained on this basis, if the aquifer is homogenous and isotropic. A solution for the case of flow to parallel drains using the Laplace formulation converges toward the solution obtained from Dupuit-Forchheimer procedures as the ratio of water-table slope to drain spacing approaches zero.

72-73:04A-002
ESTIMATING SALINITY OF STREAMS IN THE SOUTHWESTERN UNITED STATES,
Pionke, H. B., Nicks, A. D., and Schoof, R. R.
Agricultural Research Service, Chickasha, Oklahoma, Southern Great Plains Watershed Research Center.
Water Resources Research, Vol. 8, No. 6, p 1597-1604, December 1972. 3 fig, 4 tab, 9 ref.

Descriptors: *Salinity, *Streamflow, *Statistical models, *Southwest U.S., Regression analysis, Mathematical models, Base flow, Surface waters, Water chemistry, Water quality.

A model is presented for the improved estimation of stream salinity as a function of streamflow components. The proposed model was constructed by using base flow and the ratio of surface to base flow. Among individual parameters tested, the ratio of surface flow to base flow was the best salinity predictor for ephemeral streams. Conversely, total flow was the best individual predictor for the stream draining the largest watershed. The proposed model explained 77.1%-95.2% of the variability in stream salinity and never exceeded a 30% error for any stream as determined from the standard error of estimate. It was found to estimate more precisely and accurately the salinity of streams characterized by ephemeral flows than other models.

72-73:04A-003
OPPORTUNITY COSTS OF A TRANSBASIN DIVERSION OF WATER 1. METHODOLOGY,
Moncur, J. E. T.
Hawaii University, Honolulu, Department of Economics; and Hawaii University, Honolulu, Water Resources Research Center.
Water Resources Research, Vol. 8, No. 6, p 1415-1422, December, 1972. 22 equ, 6 ref.

Descriptors: *Diversion, *River basins, *Multipurpose reservoirs, *Feasibility, *Planning, *Linear programming, *Dynamic programming, *Water supply, Water demand, Reservoir releases, Optimization, Estimating, Biochemical oxygen demand, Dissolved oxygen, Southwest U.S., *Columbia River, Mathematical models, Systems analysis.
Identifiers: *Opportunity costs, *Transbasin water diversion.

Water planning agencies in arid and semi-arid regions of the southwestern states have long been under pressure to obtain water supplies sufficient to satisfy demands in their fastly growing regions. One source of supply is the possibility of importing water from rather distant river basins. A largescale transbasin water diversion project must be feasible not only in terms of the direct costs of transporting water but also in terms of the value of services foregone by the exporting region due to the diminution of its water supply. A general model is developed for estimating the opportunity costs of diverting water outside a river basin. The procedure adapts the decomposition algorithm for linear programs to optimize operations of the water system with respect to time, multiple complementary and competitive uses, and location, with allowances made for serial as well as parallel configurations of reservoirs. The algorithm solves iteratively for the optimal value of the river's services. Two solutions are sought: one assuming'natural' inflow conditions and one assuming depleted inflows to simulate the situation after a diversion. The difference between these optimal values is a measure of the opportunity costs incurred by the water-exporting region.

72-73:04A-004
STEPPED WEIR ON AN ANISOTROPIC DRAINED STRATUM OF FINITE DEPTH,
Reddy, A. S., Mishra, G. C., and Seetharamiah, K.
Indian Institute of Science, Bangalore, Department of Civil and Hydraulic Engineering.
Water Resources Bulletin, Vol. 8, No. 1, p 55-62, February 1972. 6 fig, 2 ref.

Descriptors: *Weirs, *Seepage, *Underseepage, *Anisotropy, Permeability, Alluvial channels, Flow nets, Groundwater movement, Mathematical studies.

Weirs are sometimes constructed on a two-layered soil. The lower layer may have much higher permeability when compared to that of the upper layer. In such a case the lower layer will act as a drainage layer. Further the soil may be anisotropic with respect to permeability. Using Schwarz-Christoffel transformation, the pressure distribution and exit gradients may be found for a weir on an anisotropic drained stratum. The total head at the boundary of the two strata is assumed to be constant.

72-73:04A-005
RESTORING SUBSURFACE DRAIN PERFORMANCE,
Grass, L. B., and MacKenzie, A. J.
Agricultural Research Service, Brawley, California, Imperial Valley Conservation Center.

Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IRI, p 97-106, March 1972. 9 fig, 1 tab, 5 ref, append.

Descriptors: *Subsurface drainage, *Irrigation operation and maintenance, *Clogging, *Cleaning, Irrigation, Drainage systems, Silting, Root systems, Tile drains, Failure, Gypsum, Travertine, Field investigations, Precipitation (Chemistry), Repairing, Maintenance, Incrustation, Tile drainage, Salinity, Drainage.
Identifiers: Imperial Valley (Calif), Coachella Valley (California), Sulfur oxides, Colorado River, Dissolved salts, Irrigated agriculture, Jetting, Drain tiles.

Restoration of subsurface drain performance is vitally important in preventing soil salinity buildup. Malfunctioning tile drains must be quickly recognized by effluent flow measurements, water table elevation changes, and soil profile or drain effluent salinity increases. Deposits of iron and manganese precipitates in tile drains clog the openings through which water enters, creating a serious hazard to crops resulting from rising water tables and increasing soil salinity. Chemical treatment with a 2% mixture, by weight, of sulfur dioxide gas and water has been successful in restoring drain efficiency. Other types of mineral deposits encountered are gypsum and travertine. Gypsum deposits in the form of small crystals can be easily removed by high-pressure water jetting equipment; however, large, very dense crystals cannot be broken by jetting equipment or dissolved by chemicals and affected pipes must be replaced. Travertine deposits react quickly with most acids. The accumulations of very fine soil sediments which occasionally cause tile malfunctions are most effectively removed by high-pressure jetting equipment. Accumulations of fine roots can also be removed by this method, but long flexible rotating rods with cutting blades are best for removing larger roots.

72-73:04A-006
SEEPAGE FROM SHALLOW OPEN CHANNEL,
Hunt, B. W.
Washington University, Seattle, Department of Civil Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 98, No. HY5, Paper 8875, p 779-785, May 1972. 3 fig, 4 ref, append.

Descriptors: *Canal seepage, *Open channels, *Surface-groundwater relationships, Furrow irrigation, Darcy's law, Recharge, Infiltration, Hydrogeology, Numerical analysis, Irrigation, Irrigation water.

An approximate Darcy solution was obtained for the two-dimensional seepage from an open channel upon a homogeneous, isotropic aquifer of relatively large depth. The linearized solution was obtained for an arbitrary channel cross section by assuming that the maximum channel depth is small compared to the channel width. Comparison with a known exact solution for a particular channel shape suggests that this solution is probably accurate enough for design purposes when the channel depth is less than 40% of the channel width.

72-73:04A-007
HYDRODYNAMICS OF BORDER IRRIGATION ADVANCE,
Kincaid, D. C., Heermann, D. F., and Kruse, E. G.
United States Department of Agriculture, Mitchell, Nebraska.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 674-680, July-August, 1972. 14 fig, 1 tab, 10 ref.

Descriptors: *Irrigation practices, *Irrigation design, *Border irrigation, *Infiltration rates, Irrigation systems, Computer models, Application methods, Crop production, Agricultural engineering.

A mathematical model simulating border irrigation was developed by numerically solving the hydrodynamic equations of overland flow. A power law infiltration function is used and the resistance is calculated by Manning's equation. The advance rate is controlled by the overall volume balance of the system. The moving boundary is the locus of points at some arbitrary depth. Comparisons of the model with experimental advance data, surface hydrographs and surface storage volume curves show that the model simulates border flow reasonably well with a resistance function of the form of Manning's equation. The model will describe advance for any specified inflow conditions whenever the slope, infiltration and resistance properties of the border are known.

72-73:04A-008
MATHEMATICAL MODEL OF WATER ADVANCE IN BORDER IRRIGATION,
Bassett, D. L.
Washington State University, Agricultural Engineering Department, Pullman.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 992-995, September-October, 1972. 3 fig, 12 ref.

Descriptors: *Model studies, *Surface irrigation, *Border irrigation, Irrigation practices, Mathematical models, Computer models, Infiltration rates, Agricultural engineering.
Identifiers: Water advance.

A mathematical model is presented which describes the advance of water over a dry porous bed as in border irrigation. The model uses the complete equations of continuity and motion for unsteady spatially varied flow. These are solved by the method of characteristics, with an external shape function and volume balance technique for advancing the tip. Computed solutions are compared with laboratory and field tests. Results suggest the model will predict flow with accuracy acceptable for most field use and comparable to that with which input data are described.

72-73:04A-009
SEMI-PORTABLE SHEET METAL FLUME FOR AUTOMATED IRRIGATION,
Uhl, V. W., Jr., and Garton, J. E.
Oklahoma State University, Agricultural Engineering Department, Stillwater.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 256-260, March-April, 1972. 7 fig, 7 ref.

Descriptors: *Irrigation practices, *Distribution systems, *Automation, Flumes, Irrigation design, Furrow irrigation, Irrigation, Agricultural engineering.

A sheet metal flume for automated cut-back irrigation was designed hydraulically and structurally. Preceding the structural analysis, several types of designs were investigated considering the problems of ease of assemblage in the field, support of the channel in the field, and leakage. The basic design consists of a sheet metal section supported by a structural steel angle framework. Taking the basic framework selected, several combinations of material design were considered and investigated theoretically. From these investigations three structural steel angle frameworks were built and three sizes of sheet metal sections chosen. Six combinations were tested and a final design was selected. A 230-foot section was assembled in the field for testing. Values of Manning's n were determined from gradually varied flow tests for various flows and depths of flow. The flume operated satisfactorily.

72-73:04A-010
WHEAT AND GRAIN SORGHUM IRRIGATION IN A WIDE BED-FURROW SYSTEM,
Allen, R. R., Musick, J. T.
United States Department of Agriculture, Bushland, Texas
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, p 61-63, January-February, 1972. 1 tab, 4 fig, 7 ref.
(See 72-73:02G-032)

72-73:04A-011
EFFECT OF ROUGHNESS ELEMENTS ON HYDRAULIC RESISTANCE FOR OVERLAND FLOW,
Kowobari, T. S., Rice, C. E., and Garton, J. E.
Soil Testing Services Incorporated, Northbrook, Illinois.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 979-984, September-October, 1972. 4 fig, 4 tab, 8 ref.
(See 72-73:08B-004)

72-73:04A-012
SELECTING A METHOD FOR SCHEDULING IRRIGATION, USING A SIMULATION MODEL,
Lembke, W. D., and Jones, B. A., Jr.
Illinois University, Agricultural Engineering Department, Urbana-Champaign.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 284-286, March-April, 1972. 5 fig, 1 tab, 6 ref.

Descriptors: *Irrigation practices, *Mathematical models, *Rates of application, Irrigation water, Irrigation design, Irrigation efficiency, Computer models, Soil physics, Irrigation systems.

A water balance model was used to simulate an irrigation system, in order to compare three irrigation scheduling practices on the two soils for corn in central Illinois. For soil with a water-holding capacity of 0.8 in. per ft., the practice of applying 30 percent of the available water when the soil water fell to the 70 percent level was the most profitable one. The practice of applying 40 percent of the available water when the soil water fell to the 60 percent level was not economically feasible on either soil. On soil with a water-holding capacity of 1.2 in. per ft., there was no need to measure moisture content. A satisfactory rule was to apply 1 in. of net water after any 7-day period during which less than an inch of rain had fallen.

72-73:04A-013
DESIGN CRITERIA FOR IRRIGATION SYSTEMS WITH COMPLEX PIPE LOOPS,
Edwards, D. M., and Spencer, B.
Nebraska University, Lincoln.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, p 76-78, January-February, 1972. 3 fig, 1 tab, 7 ref.
(See 72-73:08B-005)

72-73:04A-014
SOIL AND WATER LOSSES AS AFFECTED BY TILLAGE PRACTICES,
Onstad, C. A.
United States Department of Agriculture, Agricultural Research Service, Soil and Water Conservation, Brookings, South Dakota.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 287-289, March-April, 1972. 1 fig, 6 tab, 8 ref.
(See 72-73:02J-008)

72-73:04A-015
PASTURE IRRIGATION WITH A CENTER-PIVOT SPRINKLER SYSTEM,
Somerhalder, B. R., and Clanton, D. C.
Nebraska University, Agricultural Engineering Department, North Platte.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 902-904, 908, September-October, 1972. 1 fig, 6 tab.

Descriptors: *Irrigation practices, *Sprinkler irrigation, *Pasture management, Carrying capacity, Forages, Pasture, Crop production.
Identifiers: Center-pivot sprinklers, Beef production.

Irrigated cool season pasture under a 52-acre center-pivot sprinkler system was grazed with beef cattle for two years at the University of Nebraska, North Platte Station. Three classes of animals -- cows and calves, yearlings, and weaned calves -- were grazed at different times during each year. Average investment and operating costs for two years of forage production was $126.04 per acre: average beef gain was 748 lb. per acre. This resulted in a feed cost of 16.8 cents per pound of gain.

72-73:04A-016
HYDRAULICS OF A CENTER PIVOT SYSTEM,
Chu, S. T., and Moe, D. L.
South Dakota State University, Brookings.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 894-896, September-October, 1972. 3 fig, 1 tab, 4 ref.
(See 72-73:08B-006)

72-73:04A-017
A COMPUTERIZED SOLUTION FOR BENCH LEVELING DESIGN,
Smith, E. F., and Edwards, D. M.
Archer Daniels Midland Company, Lincoln, Nebraska.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 667-669, July-August, 1972. 3 fig, 8 ref.

Descriptors: *Computer programs, *Land forming, Land development, Irrigation practices, Agricultural engineering, Land use.
Identifiers: Land grading.

The analysis presented in this paper can be used on all digital computers. Solutions to the program for reshaping the surface of the land resulted in a large savings in cost and time as compared to the trial-and-error procedure without the computer. It also made available the possibility of analyzing the same data with various sets of input restrictions. However, certain limitations are imposed when using this program: (a) Only rectangular areas are adaptable to this program. (b) The entire final surface of the bench is graded to a uniform plane. (c) The digital computer divorces all factors of human judgment from the solution. Human judgment is the key to successful design when applied before data reaches the computer.

72-73:04A-018
IRRIGATION IN ANCIENT MESOPATAMIA,
Kang, S. T.
Illinois University, World Heritage Museum, Urbana.
Water Resources Bulletin, Vol. 8, No. 3, p 619-624, June, 1972. 2 fig.

Descriptors: *Irrigation practices, *Salinity, Crop production, History.

A translation of the cuneiform text written on clay tablets is presented. These writings are the day-by-day records of early irrigation activities. The problems of salinization and silting were very evident. The government of modern Iraq is using this information to locate and restore some of the systems. Decreased production, with time, is shown. These writings can be of benefit to modern man.

72-73:04A-019
INTERNATIONAL MANAGEMENT OF THE RIO GRANDE BASIN - THE UNITED STATES AND MEXICO,
Day, J. C.
Western Ontario University, London, Canada.
Water Resources Bulletin, Vol. 8, No. 5, p 935-947, October, 1972. 3 fig, 18 ref.
(See 72-73:02E-006)

72-73:04A-020
SUBSURFACE DISTRIBUTION OF NONUNIFORMLY APPLIED SURFACE WATERS,
Hart, W. E.
Colorado State University Agricultural Engineering Department, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 656-661, 666, July-August, 1972. 14 fig, 1 tab, 13 ref.

Descriptors: *Irrigation practices, *Irrigation design, *Sprinkler irrigation, *Irrigation systems, Uniformity coefficient, Computer models, Application methods, Application equipment, Sprinkling, Crop production.

Sprinkler irrigation systems are evaluated by determining the uniformity of water as it is applied to the surface of the ground. The plant responds to the distribution of the water as it occurs within the soil. The gradients existing within the unevenly wetted soil move moisture laterally (and vertically) within the profile, causing the water within the soil to be more uniformly distributed than indicated by the initial, surface-measured distribution. The extent of this movement throughout the soil, within a reasonable length of time, appears to be a function of the following variables: initial moisture content, average application rate, distribution of water as applied to the surface, length modulus, soil type, and total applied water. It is apparent that current methods of designing irrigation systems, which are based almost exclusively on anticipated initial uniformity, are inadequate if the aim of the design is to provide the most economical system possible.

72-73:04A-021
VOLUME BALANCE METHOD FOR COMPUTING INFILTRATION RATES IN SURFACE IRRIGATION,
Lal, R., and Pandya, A. C.
Orissa University of Agriculture and Technology, Bhubaneswar, India.
Transactions of the American Society of Agricultural Engineers, Vol. 15,
No. 1, p 69-72, January-February, 1972. 4 fig, 2 tab, 7 ref.

Descriptors: *Irrigation practices, *Irrigation efficiency, Infiltration, Surface irrigation, Irrigation design, Infiltration rates, Unsaturated flow, Irrigation, Irrigation engineering.

Based upon the equation of continuity an empirical infiltration equation can be developed from the water advance measurements during surface irrigation. This so called volume balance method of calculating infiltration rate from surface irrigation data is most practical as it presents the actual mean conditions that exist during irrigation application. For high degree of accuracy, small time increment may be taken and calculations involved can be conveniently done by using computer techniques. An example of computation based upon field data collected at the Indian Institute of Technology, Kharagpur, India, has been presented to show how the method is used. Copies of the computer program are available on request from the authors.

72-73:04A-022
TRANSPORT OF SOIL PARTICLES BY SHALLOW FLOW,
Foster, G. R., and Meyer, L. D.
United States Department of Agriculture, Lafayette, Indiana.
Transactions of the American Society of Agricultural Engineers, Vol. 15,
No. 1, p 99-102, January-February, 1972. 3 fig, 2 tab, 15 ref.
(See 72-73:02E-007)

72-73:04A-023
SELF-CLOSING IRRIGATION PIPE VALVE,
Haise, H. R., and Payne, M. L.
United States Department of Agriculture, Fort Collins, Colorado.
Journal of the Irrigation and Drainage Division, American Society of Civil
Engineers, Vol. 98, No. IR3, p 517-522, September, 1972. 5 fig, 5 ref.

Descriptors: *Irrigation systems, *Distribution systems, *Valves, *Remote control, Turnouts, Pipe flow, Pipes, Irrigation engineering, Irrigation design.

A low-head self-closing hydraulic diaphragm irrigation valve that operates on water pressure in the pipe distribution system has been developed and successfully tested. The valve requires a pilot valve and control lines for remote operation. Pressure head in the system plus velocity head from a pilot tube, and the differential area of the valve, combine to make closure possible. Possible uses include control of reservoir outlets, water releases from riser valves, and routing water in storm sewers to maximize design capabilities. No outside power source is required.

72-73:04A-024
SHAPE FACTORS IN IRRIGATION WATER ADVANCE EQUATION,
Singh, P., and Chauhan, H. S.
Agricultural University, Agricultural Engineering Department, Pantnagar,

Nainital, India.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers. Vol. 98, No. IR3, p 443-458, September, 1972. 10 fig, 1 tab, 9 ref.
(See 72-73:02G-046)

72-73:04A-025
WATER REQUIREMENTS OF ROSTERED IRRIGATION SCHEMES,
Fitzgerald, P. D., and Arnold, G. C.
Department of Agriculture, Irrigation Research Station, Ashburton, New Zealand.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR1, p 91-96, March, 1972. 1 fig, 3 tab, 4 ref.

Descriptors: *Irrigation practices, *Irrigation systems, Water distribution (applied), *Computer models, Distribution systems, Water delivery, Water demand, Irrigation engineering, Irrigation efficiency, Surface irrigation, Irrigation, Water allocation (policy), Water requirements, Soil moisture.
Identifiers: New Zealand, Irrigation scheduling.

A method is given whereby the water requirements of a rostered (rotation) irrigation scheme can be determined by considering the length of the roster period and the calculated soil moisture deficit at which irrigation is applied. From this the storage likely to be needed can be calculated. The method is computer processed so variations can easily be studied. An example of its application to the Irrigation Schemes of Mid-Canterbury, New Zealand, is given.

72-73:04A-026
RECESSION FLOW IN SURFACE IRRIGATION,
Wu, I.
Hawaii University, Honolulu.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR1, p 77-90, March, 1972. 6 fig, 1 tab, 9 ref.
(See 72-73:02E-008)

72-73:04A-027
OPERATION AND MAINTENANCE OF IRRIGATION AND DRAINAGE SYSTEMS: SECTION III. - OPERATION,
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR3, p 237-338, September, 1973. 36 fig, 28 ref.

Descriptors: *Drainage, *Drainage systems, *Irrigation, *Irrigation systems, Operations, Water distribution (applied), Water management (applied), Water reuse.

For the purpose of this manual, the subject of operation is treated by a discussion of the factors essential to good water management on an irrigation and drainage system; the staff necessary to accomplish the work and its responsibility; operating practices and procedures for the handling, movement, disposal or reuse of water; and the value of good records and communications in these operations. The irrigation system referred to in this manual is that generally referring to movement of water from its source to the user, and is that system prevalent in arid and semiarid areas as well as in humid areas. The use of the term drainage system refers to systems in which removal of excess surface water seasonally is normally a necessity.

72-73:04A-028
PHYSICAL MODEL STUDY OF BORDER-STRIP IRRIGATION,
Jobling, G. A., and Turner, A. K.
Engineering, Irrigation, and Water Supply Commission, Queensland, Australia.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR4, p 493-510, December, 1973. 14 fig, 1 tab, 20 ref.

Descriptors: *Hydraulic models, *Infiltration, *Irrigation systems, Hydraulics, Model studies, Roughness (hydraulic), Surface irrigation, Uniform flow, Water distribution (applied).

A physical model of an irrigation border was constructed and tested. Equations are developed which describe the profile of the water advancing down the border, the rates of advance, and recession after the inflow is cut off, in terms of inflow, infiltration, slope, and surface roughness. These equations are simplified to a form more suitable for use in design. An illustrative analysis is done to determine correct inflows and cutoff times needed to uniformly irrigate to a desired depth.

72-73:04A-029
PROBLEMS OF CHOOSING IRRIGATION TECHNIQUES IN A DEVELOPING COUNTRY,
Soltani-Mohammadi, G. R.
Panlavi University, Department of Agricultural Economics, Shiraz, Iran.
Water Resources Research, Vol. 8, No. 1, p 1-6, February, 1972. 4 tab, 13 ref.

Descriptors: *Irrigation practices, *Economics, *Comparative costs, Computer models, Irrigation engineering, Irrigation design, Irrigation systems, Surface irrigation, Sprinkler irrigation.

A linear programing model is developed to select between modern surface and portable or semiportable sprinkler systems for two irrigation projects in Iran. Skilled labor is included in the model as one of the major limiting factors. For the specified conditions and assumptions, a portable or semiportable sprinkler system is indicated to be economically superior to a modern surface irrigation system for the development of new lands. However in lands where a modern surface irrigation system has already been installed the transformation to sprinkler irrigation is not feasible. A completely automated sprinkler system is not indicated for either set of conditions in Iran. Primitive irrigation was not included in this study because of lack of data. Welfare effects of the choice of techniques are indicated.

72-73:04A-030
DYNAMICS OF ION TRANSPORT DURING MOISTURE FLOW FROM A DOUGLAS-FIR FOREST FLOOR,
McColl, J. G.
Washington University, Seattle.
Soil Science Society of America Proceedings, Vol. 36, No. 4, p 668-674, July-August 1972. 4 fig, 3 tab, 32 ref. NSF Grant GB-8125.

Descriptors: *Ion transport, *Leaching, *Forest soils, *Lysimeters, Monitoring, Forests, Forest management, Douglas fir trees, Temperature, Soil water movement, Clear-cutting.
Identifiers: *Automated field-monitoring system.

Ion transport was studied during periods of moisture flow from the forest floor using automated equipment in a second-growth Douglas-fir forest in western

Washington. The transport process was related to the temperature in the forest floor, the duration of time before flow, and the amount of moisture flow. The relationship of seasonal climatic changes to the ion transport process, and the changes in solution concentration during wetting cycles are described. The study provides a base for predicting possible effects of manipulating natural forest ecosystems. A warning is given of possible effects of some common forest-management practices.

72-73:04A-031

CONSIDERATIONS FOR EFFECTIVE SLOPING LAND DRAINAGE SYSTEMS,

Benoit, G. R., and Bornstein, J.

Agricultural Research Service, Burlington, Vermont, Soil and Water Conservation Research Division.

Soil Science Society of America Proceedings, Vol. 36, No. 5, p 819-823, 1972. Illus.

Identifiers: Bypass, Climate, *Drainage systems, Equation, Flow, *Land drainage (sloping), Seismograph analysis, Soils, Transpiration, Evapotranspiration, *Vermont, Water balance.

A 12-plot sloping land drainage study in East Franklin, Vermont, is located on a model Cabot silt loam-a poorly-drained glacial till fragipan soil. The plots consist of all combinations of 2 depths (30 and 51 cm) and 2 spacings (61 and 122 m) of surface drains (diversions) and 3 spacings (none, 30.5, and 61 m) of subsurface drains located 102 cm deep. Drainage, soil water, and climatic data were used to evaluate a water balance equation for each drain for 6 selected drainage intervals. A seismographic analysis showed vibrations in soil depth as related to bedrock configuration. The results showed great variation in drain performance between drains in the same interval and between intervals for the same drain. Wide differences observed between values for drainage plus soil water storage and rainfall minus potential evapotranspiration seemed to be related to initial soil water content, the gain or loss of soil water, and the magnitude of potential evapotranspiration. Greatest drainflow occurred from those subdrains located at points of shallowest soil depths with bypass flow occurring under the drains particularly during saturated conditions. A drainage system for wet sloping soil should include: surface drains for controlled removal of snowmelt surface runoff; subsurface drains located at the top of bedrock dropoffs, where the bedrock is closest to the soil surface; subsurface drains systematically spaced between these drains to intercept bypass flow before it reaches downslope soil surface areas.

72-73:04A-032

TWO- AND THREE-DIMENSIONAL INFILTRATION: SEEPAGE FROM IRRIGATION CHANNELS AND INFILTROMETER RINGS,

Youngs, E. G.

Agricultural Research Council, Cambridge (England), Unit of Soil Physics.

Journal of Hydrology, Vol. 15, No. 4, p 301-315, April 1972. 17 fig, 2 tab, 16 ref, append.

Descriptors: *Seepage, *Canal seepage, *Laboratory tests, Leakage, Hydraulic models, Water loss, Analog models, Model studies, *Infiltration, Saturated flow, Unsaturated flow.

Steady seepage rates from flat-bottomed channels and channels of semi-circular cross-section were determined in laboratory tank experiments using various sands. Good agreement was found with the theoretical relationships, which assume the flow to be confined to a saturated region bounded by a capillary-fringe surface, and to be uniform and vertical at great depths. The steady large-time seepage rates were also obtained in laboratory sand-tank experiments for the three-dimensional cases of seepage from circular shallow ponds and hemispherical sources. These agreed with relationships obtained using an electrolytic tank analog with approximate boundary conditions assumed for the flow region. A method of analysis of largetime seepage measurements from irrigation channels and infiltrometer rings yields the hydraulic conductivity and pressure head at the wetting front.

72-73:04A-033
WATER TABLE DRAWDOWN AROUND AN OPEN DITCH IN ORGANIC SOILS,
Boelter, D. H.
North Central Forest Experiment Station, Grand Rapids, Minnesota, Northern Conifers Laboratory.
Journal of Hydrology, Vol. 15, No. 4, p 329-340, April 1972. 6 fig, 1 tab, 13 ref.

Descriptors: *Drawdown, *Peat, *Organic soils, *Drainage, *Ditches, Water table, Drains, Water levels, Groundwater movement, Land reclamation, Water yield improvement, Hydraulic conductivity, Forest management.

Water-level control is a potential method of improving the amount and distribution of runoff from peatlands as well as their capability to produce timber, agricultural crops, and wildlife. The effectiveness of this practice varies with the hydraulic conductivity of the peat materials through which the water must flow. An open ditch hastened the drainage of water from surface or near surface horizons of fibric (moss) peat on a typical lake-filled organic soil. However, it had little influence on the water table beyond 5 m from the ditch when the water table was in deeper horizons of moderately decomposed (hemic) peat. In an organic soil with less decomposed (fibric) peat throughout several m depth at the surface a similar ditch influenced the water table as far as 50 m from the ditch.

72-73:04A-034
CONTROLLED INSTANTANEOUS APPLICATION OF FREE WATER TO A POROUS SURFACE,
Swartzendruber, D., and Asseed, M. S.
Purdue University, Agricultural Experiment Station, West Lafayette, Indiana.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 967-968, November-December, 1973. 1 fig.

Descriptors: *Infiltration, *Infiltration rates, *Porous media, Seepage, Flow measurement, Groundwater movement, Hydraulic conductivity, Porosity, Soil physics.

Instantaneous application of free water to a porous-medium surface is achieved essentially by a device in which the central feature is a plastic plate perforated with small holes. The pressure head of the water can be controlled at a preselected value between 0 and 1 cm. Water enters the porous medium at essentially zero external flow resistance, while volume and time of entry can be measured accurately. No lateral flow of free water occurs, thus eliminating the disturbing effects of such flow on the porous-medium surface.

72-73:04A-035
THEORY OF A RECTANGULAR GRAVEL ENVELOPE IN DRAINAGE DESIGN,
Kirkham, D., and Selim, M. S.
Iowa State University, Ames Department of Agronomy.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 517-521, July-August 1973. 5 fig, 5 tab, 8 ref.

Descriptors: *Subsurface drains, *Subsurface drainage, Soil water movement, Equations.
Identifiers: Gravel-packed drain tubes.

A theory was developed to determine the radius of a circular drain which is equivalent to a square drain. A square drain is encountered in practice when a gravel envelope of square cross section is placed around a subsurface circular drain. The resistance of the gravel to flow was neglected. The square drain tube was analyzed for two cases: (1) when an impermeable barrier was at great depth below the square drain tube center, and (2) when the bottom edge of the square drain tube lay on a plane impermeable barrier. In both cases it was assumed that the length of the edge of the square drain tube was small compared with the distance from the drain's center to a water table over the drain, and that the drain ran full. For case 1 an equivalent circular drain tube of radius 1.1772 times the half-width of the square drain tube may be used to replace the square drain tubes. If the square drains lie on the impervious layer, as in case 2, the radius of the equivalent circular drain is 1.1037.

72-73:04A-036
STUDIES ON SEEPAGE FROM CANALS WITH PARTIAL LINING,
Subramanya, K., Madhav, M. R., and Mishra, G. C.
Indian Institute of Technology, Department of Civil Engineering, Kanpur, India.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY12, p 2333-2351, December, 1973. 11 fig, 6 ref.

Descriptors: *Seepage, *Seepage control, *Canals, Canal seepage, Canal linings, Permeability, Phreatic lines, Hydraulics, Canal design.

A study of seepage from partially lined trapezoidal canals in a homogeneous isotropic porous medium of large depth is done using inversion of hodograph and Schwarz-Christoffel transformation. The two cases studied are: (1) Seepage from canals whose sides are lined but bottom unlined; and (2) seepage from canals whose bottom is lined but sides unlined. It is found that for every side slope of the canal there is a particular aspect ratio at which the sides lining or bottom lining results in the same reduction of seepage. For canals having an aspect ratio more than this, bottom lining is more effective and for a lesser aspect ratio, sides lining will be more effective. For a canal having an aspect ratio of 9 and a side slope of 2.5:1, a 50% reduction in seepage is ensured by sealing the bottom. The loci of the phreatic lines, resulting in the aforementioned two cases, are also studied.

72-73:04A-037
SOLUTIONS FOR LATERAL OUTFLOW IN PERFORATED CONDUITS,
Berlamont, J., and Van der Beken, A.
State University of Ghent, Department of Civil Engineering, Ghent, Belgium.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY9, p 1531-1549, September, 1973. 11 fig, 3 tab, 17 ref.

Descriptors: *Drainage, *Irrigation, *Hydraulics, Pipe flow, Sprinkler irrigation, Sewage disposal, Water distribution (applied).

This paper gives general solutions for obtaining a uniform lateral outflow, either by varying the perforation area or the cross-sectional area. The distribution of the lateral outflow in a conduit with constant cross section and constant perforation area is analyzed under normalized form. Appropriate flow parameters are introduced which allow for inertia or pressure recovery, velocity distribution, laminar or turbulent out-flow, and laminar and turbulent smooth or rought flow. All results are presented in diagrams. A design rule for nearly uniform discharge under turbulent pipe flow conditions is derived. The agreement between experimental data and the presented solutions, when the velocity correction coefficient is properly chosen, sustains the actual approach.

72-73:04A-038
A SIMULATION MODEL FOR EVALUATING IRRIGATION MANAGEMENT PRACTICES,
Morey, R. V., and Gilley, J. R.
Minnesota University, Agricultural Engineering Department, Saint Paul.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 5, p 979-983, September-October, 1973. 5 fig, 16 ref.

Descriptors: *Computer models, *Irrigation practices, *Management, Farm management, Land management, Water management (applied).

A soil moisture budget which can be used to evaluate irrigation management practices has been presented. Results of a calibration-verification procedure were included. The model was used to test several irrigation management policies for two soil types and 24 years of weather data for St. Cloud, Minnesota. The results give a good insight into the variability in year-to-year transpiration response under no irrigation. They also show the effect of irrigation policies on improvement of the transpiration ratio. The simulation results in conjunction with assumptions and additional information about an individual operator's yield potential, management practices, etc., should be useful in helping an irrigation operator make better decisions concerning irrigation feasibility and scheduling procedures. As such, the model should be a useful aid in irrigation management decisions.

72-73:04A-039
SURFACE IRRIGATION UNDERGROUND PIPELINES WITH MOVABLE RISERS,
Varlev, I.
Institute of Soil Science, Academy of Agricultural Sciences, Sofia, Bulgaria.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 4, p 787-789, July-August, 1973. 7 fig, 3 ref.

Descriptors: *Irrigation practices, *Surface irrigation, Furrow irrigation, Border irrigation, Pipelines, Water distribution (applied), Water supply, Irrigation systems.

Investigations have been successfully completed in the development of surface irrigation systems where the water is distributed by underground lateral pipelines having either removable or movable risers which supply water to either furrows or borders. The pressures used in these pipelines is only 5 to 6 feet of water, which allows the use of the more economical low-pressure pipe materials. Full automation of the delivery from lateral-to-lateral can be achieved. These systems have been designed to achieve efficient use of water, while minimizing labor requirements.

72-73:04A-040
EVALUATING OUTDOOR WEATHERABILITY OF BUTYL RUBBER SHEETING UNDER STRESS,
Dedrick, A. R.
United States Water Conservation Laboratory, Phoenix, Arizona.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 4, p 769-772, July-August, 1973. 6 fig, 2 tab, 11 ref.

Descriptors: *Rubber, *Membranes, Weathering, Deterioration, Stress, Canal linings, Impervious membranes, Waterproofing.

Seasonal variation of deterioration and the effect of membrane elongation and thickness on rate of deterioration were determined for one butyl rubber formulation at Logan, Utah. Deterioration rates were greatest during the high temperature part of the year. Deterioration rates increased as elongation increased and as membrane thickness decreased. Short exposure times (a few weeks) can be used to evaluate the potential life of a butyl rubber membrane when thickness, stress (elongation), and season are properly considered.

72-73:04A-041
CULVERTS FOR FLOW MEASUREMENT IN IRRIGATION SYSTEMS,
Skogerboe, G. V., Walker, W. R., and Boonkird, V. S.
Colorado State University, Agricultural Engineering Department, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 2, p 287-293, March-April, 1973. 8 fig, 2 tab, 9 ref.

Descriptors: *Flow measurement, *Open channel flow, *Culverts, Flow rates, Water measurement, Gaging stations, Flumes.

This study has shown that the submerged flow analysis used for flow measuring flumes and weirs can be applied to free surface outlet control flow in culverts. Also, discharge ratings for horizontal culverts can be graphically shown on a single plot. Such a plot covers the three flow conditions investigated, which are inlet control, free surface outlet control, and submerged outlet control. The results of this study have clearly shown that culverts can definitely be used as flow measuring structures in irrigation systems. Thus, existing culverts could be utilized for providing discharge measurements. Also, small culverts could be employed as portable flow measuring devices. The assumption that nl = 1.5 was used to simplify the analysis. Further study should be undertaken to remove this assumption from the flow analysis. Then, generalized discharge ratings could be developed for a wide variety of inlet, barrel, and outlet culvert geometries.

72-73:04A-042
IRRIGATION NUMBER--A NEW TECHNIQUE TO EVALUATE IRRIGATION ADVANCE DISTANCE,
Sastry, G., and Agarwal, S. C.
Indian Institute of Technology, Department of Agricultural Engineering, Kharagpur, West Bengal, India.
Journal of Agricultural Engineering Research, Vol. 18, No. 3, p 189-195, September, 1973. 1 fig, 1 tab, 12 ref.

Descriptors: *Irrigation design, *Irrigation engineering, *Irrigation practices, Surface irrigation, Irrigation efficiency, Irrigation systems.

Prediction of irrigation advance distance for a given set of initial conditions such as slope of land surface, inflow stream per unit top width of flow, infiltration characteristics and hydraulic conductivity of soil bed, is important in order to design efficient surface irrigation systems. A dimensional analysis of variables involved in water advance phenomenon has been made to derive a satisfactory equation. The data available at this Research Station has been analyzed and fitted by least square method of curve fitting to yield an equation of the type M = A(N)B. The slope of each curve B is observed to be fairly constant and coefficient A has been related with irrigation number. An irrigation advance function relating these dimensional parameters is proposed.

72-73:04A-043
DEVELOPMENT OF AUTOMATED SURFACE IRRIGATION,
Pohjakas, K.
Agriculture Canada, Research Branch, Research Station, Lethbridge, Alberta.
Canadian Agricultural Engineering, Vol. 14, No. 2, p 72-74, December, 1972.

Descriptors: *Irrigation practices, *Irrigation systems, Automation, Automatic control, Surface irrigation, Furrow irrigation, Border irrigation, Irrigation.

Surface irrigation by manual methods, because of its high labor requirement, is rapidly being replaced by automated sprinkler irrigation. Various gates, valves, dams, and weirs have been developed that, when used, enable a surface irrigation system to function automatically or by remote control. These components must be reliable, inexpensive, and simple to operate. Hardly any of the recently developed components are being manufactured for commercial use. Automated equipment can reduce the labor requirement of the traditional surface irrigation. Further developmental work, field testing, and commercial production of automatic water control devices are necessary to make surface irrigation competitive with other more automatic systems of irrigation.

72-73:04A-044
TRICKLE IRRIGATION IN AUSTRALIA,
Milne, J.
Irrigation Journal, Vol. 23, No. 6, p 21, November-December, 1973. 1 fig.

Descriptors: *Irrigation practices, *Surface irrigation, Application equipment, Soil moisture, Horticulture, Australia.

A brief history of trickle irrigation in Australia is given. The use of irrigation scheduling in the operation of the trickle system is also noted.

72-73:04A-045
1973 IRRIGATION SURVEY,
Irrigation Journal, Vol. 23, No. 6, p 11-20, November-December, 1973.

Descriptors: *Irrigation, *Irrigation practices, Irrigation systems, Surveys.

A state-by-state summary of irrigated acreage for selected years since irrigation was begun in the state. The following is also given: percent change per year, amount sprinkled, type of power used by percent, method of irrigation by method, irrigated acreage by crop, and amount irrigated by gravity.

72-73:04A-046
IRRIGATION SURVEY,
Irrigation Journal, Vol. 22, No. 6, p 9-18, November-December, 1972.

Descriptors: *Irrigation, *Irrigation practices, Irrigation systems, Surveys.

A state-by-state summary of irrigated acreage for selected years since irrigation was begun in the state. The following is also given: percent change per year, amount sprinkled, type of power used by percent, method of irrigation by method, irrigated acreage by crop, and amount irrigated by gravity.

72-73:04A-047
TYPES OF IRRIGATION SYSTEMS,
Sneed, R. E.
North Carolina State University, Biological and Agricultural Engineering, Raleigh.
Irrigation Journal, Vol. 23, No. 5, p 6-9, September-October, 1973.

Descriptors: *Irrigation, *Irrigation systems, Irrigation practices, Application equipment, Distribution systems.

A brief history of irrigation is presented along with census figures of the growth of irrigation in recent years. The types of irrigation systems are discussed. The limitations and requirements of each type are discussed briefly. The entire article is written on a non-technical format.

72-73:04A-048
CONTROLLED SPRINKLER IRRIGATION SYSTEM FOR EQUALIZED WATER DISTRIBUTION DEVELOPED IN ISRAEL,
Rhodesia Agricultural Journal, Vol. 69, No. 4, p 75-76, July-August, 1972.
2 fig.

Descriptors: *Irrigation practices, *Distribution systems, Irrigation systems, Sprinkler irrigation, Application equipment, Irrigation efficiency.

A new irrigation system has been developed in Israel to achieve maximum controlled water distribution on permanent set sprinkler schemes. Equalized water distribution with the new sprinkler, offers the obvious advantage of ensuring against over-saturating areas served by the first sprinklers or under-irrigating the last points in the network. It prevents water wastage resulting from over-discharge in the first units to compensate for the loss caused by the drop of pressure--up to 20 percent--as the result of friction over the length of the irrigation pipe and changes in topography experienced in conventional systems. The savings in water due to complete regulation of the outflow of each sprinkler is said to range from five to 15 percent of the total water use for a given plot, depending upon pressure and topographical conditions. These are low discharge sprinklers designed for use in all types of fruit orchards for under-the-foliage fixed irrigation.

72-73:04A-049
SCHEDULING IRRIGATIONS WITH HIGH-SPEED DATA FROM A COMPUTER,
Milligan, T.
Irrigation Age, Vol. 7, No. 10, p 4, 10, 11, May, 1973.

Descriptors: *Irrigation, *Scheduling, Irrigation practices, Computer models, Irrigation systems.
Identifiers: Irrigation scheduling, Computer irrigation.

The workings of a commercial irrigation scheduling firm in Idaho are discussed. The firm is based on the program developed by Dr. Marvin Jensen at the Kimberly Research Center.

72-73:04A-050
CLASS 'A' PAN AND IRRIGATION SCHEDULING,
Milligan, T.
Irrigation Age, Vol. 7, No. 10, p 12-17, May, 1973. 5 fig, 2 tab.

Descriptors: *Irrigation, Irrigation practices, Irrigation design, Application equipment, Distribution systems.
Identifiers: Irrigation scheduling.

A method is presented whereby a Class A evaporation pan can be used to help schedule irrigation. The method was developed to be used by non-technical personnnel. While this method is not as exotic and complete as those using a computer, it is an economical working aid to the farmers.

72-73:04A-051
SOLID SET ON PECANS,
Irrigation Age, Vol. 7, No. 6, p 30-32, January, 1973. 6 fig.

Descriptors: *Irrigation systems, *Sprinkler irrigation, Surface irrigation, Irrigation practices, Application equipment, Supplemental irrigation, Pecans.
Identifiers: Solid Set.

A buried solid set sprinkler system is being used on a large pecan orchard. The Buckner sprinkler heads used are 1/8-inch, low trajectory with an angle of 20 degrees so as to keep the water under the trees as much as possible. Low foliage on the trees is kept pruned off to facilitate a more even water pattern and uniform wetting of the area around the tree. Eighteen sprinklers take care of an acre and each acre has 36 trees. The manually operated system on phase one will cover the 1,027 acres in 12 days. Each set is for 24 hours. Water is supplied from river pumps which pump into a 300,000 gallon reservoir. Two turbine pumps rated at 5,600 gpm push the water from the river through a 22-inch pipeline to the reservoir. Three 8-inch horizontal centrifugal pumps are used to bring water out of the storage tank under a pressure of about 75 pounds. The sprinklers are operated at 55 to 60 pounds psi.

72-73:04A-052
CENTER PIVOTS ON ALFALFA,
Irrigation Age, Vol. 7, No. 6, p 28-29, 60-61, January, 1973. 3 fig.

Descriptors: *Irrigation systems, *Sprinkler irrigation, *Surface irrigation,

Irrigation practices, Application equipment, Corn, Alfalfa.
Identifiers: Center Pivot.

Center pivot sprinklers are being used in northwestern Oklahoma to transform sparsely vegetated range land into productive alfalfa and corn fields. The 5,340 acres are divided into 29 circles ranging in size from 160 to 240 acres. The soil types range from deep sand to sandy clay. The wide variation in application rates possible with the sprinkler systems make them ideally suited for the project. Water for the system is provided by a series of wells.

72-73:04A-053
BIG GUNS AND BLACK, WAXY GUMBO,
Milligan, T.
Irrigation Age, Vol. 7, No. 6, p 26-27, January, 1973. 1 fig.

Descriptors: *Irrigation practices, *Sprinkler irrigation, Crop response, Crop production, Alfalfa.

A farmer and a rancher in the midst of the Blackland heavy clay soil area, near Dallas, Texas, are supplemental irrigating using big gun sprinklers. The sprinklers deliver 4-1/2 acre inches of water in 20 hours on 10 acres. Five cuttings of hay were produced averaging 1000 bales per cutting.

72-73:04A-054
SPRINKLIGATION SPECIAL,
Irrigation Age, Vol. 7, No. 6, p 17-19, January, 1973. 2 fig, 1 tab.

Descriptors: *Irrigation, *Irrigation practices, *Sprinkler irrigation, Surface irrigation, Irrigation systems.

On many soil types, sprinkler irrigation is the only proper choice...the deep sands, the sandy loams...fields of complex and undulating topography and soils whose productivity would be permanently impaired by or made costly to restore if leveled for gravity. And, sprinklers open the way to "spoon" feed water and "spoon' feed plant nutrients; and often get more production per unit of water and nutrients applied.

72-73:04A-055
GATED PIPE AND SIPHON TUBES,
Irrigation Age, Vol. 7, No. 8, p 30-31, 34, March, 1973. 1 fig.

Descriptors: *Irrigation practices, *Furrow irrigation, Application equipment, Surface irrigation, Irrigation systems, Siphons.

Comparison of a Nebraska farmer's experience with gated pipe and siphon tubes. He finds that the gated pipe saves both water and labor.

72-73:04A-056
UNCONVENTIONAL FURROW IRRIGATION,
Irrigation Age, Vol. 7, No. 8, p 36-37, March, 1973. 1 fig.

Descriptors: *Irrigation practices, *Furrow irrigation, Automation, Surface irrigation, Application equipment, Irrigation systems.

In recent years, Texas A & M scientists at El Paso developed a variable row spacing system for irrigated cotton that greatly reduced water needs. The system involved the use of 80-inch spaced furrows separated by wide, flat beds. The space between the rows of cotton on each side of the furrow was 26 inches. This system reduced the size of seasonal irrigations from six to three inches per application and lowered total water use by 54 percent compared to 40-inch rows watered in every furrow.

72-73:04A-057
AUTOMATED FURROW IRRIGATION,
Milligan, T.
Irrigation Age, Vol. 7, No. 8, p 24-25, March, 1973. 1 fig.

Descriptors: *Irrigation practices, *Furrow irrigation, Automation, Surface irrigation, Application equipment, Irrigation systems.

Automation of the gated pipe system was made possible by an 18-inch air actuated valve. The valve connects to a riser on a buried pipeline or a tee in an aboveground supply line. Gated pipe is connected to the valve to distribute the water down the furrows. The valve may be six or eight inches in diameter, depending on the size of the gated pipe. The nylon-reinforced butyl rubber diaphragm is inflated to stop the water flow through the valve. The valve will fully close when one psi pressure more than the pressure in the supply pipeline is applied. For instance if the water pressure in the mainline is three psi, four psi air pressure from the compressor was needed to completely shut off the water. The Nebraska workers estimate a full quarter-section of land can be equipped for automated furrow irrigation for about the same money it takes to equip a quarter section with center-pivot sprinkler...$16,000 to $20,000.

72-73:04A-058
DRIP IRRIGATION: TEXAS STYLE,
New, L.
Irrigation Age, Vol. 7, No. 11, p 19-21, 23, June, 1973. 1 fig, 1 tab.

Descriptors: *Irrigation practices, *Surface irrigation, Irrigation systems, Application equipment, Distribution systems, Irrigation design.

Drip irrigated field tests on West Texas orchards, South Plains greenhouses and Dawson County row crops have recently been initiated. Preliminary results of these tests are most favorable and Texas farmers seem pleased at the prospect of this relatively new form of irrigation.

72-73:04A-059
DRIP COUNTRY, U.S.A.,
Hutto, H., Jr.
Irrigation Age, Vol. 7, No. 11, p 32-35, June, 1973. 34 fig.

Descriptors: *Irrigation practices, *Surface irrigation, Irrigation systems, Application equipment, Distribution systems, Irrigation design.

A pictorial tour of drip irrigation country, systems, crops, types of emitters, hardware, and techniques peculiar to this type of irrigation.

72-73:04A-060
THE HISTORY OF DRIP IRRIGATION,
Gustafson, C. D.
California University, Farm Advisor, San Diego County.
Irrigation Age, Vol. 7, No. 11, p 4-6, June, 1973. 1 fig.

Descriptors: *Irrigation practices, Surface irrigation, Irrigation, Distribution systems, Irrigation programs.
Identifiers: Drip irrigation, Trickle irrigation.

Drip irrigation's history from the first research in Israel to later studies in the United States, Italy, Japan, Australia, and Mexico is reviewed. New methods along with a forecast for the future are outlined.

72-73:04A-061
HOW TO DRIP IRRIGATE,
Irrigation Age, Vol. 7, No. 11, p 7-8, 10, 14, June, 1973.

Descriptors: *Irrigation practices, *Surface irrigation, Application equipment, Irrigation systems.
Identifiers: Drip irrigation.

A general overview of drip irrigation is presented. Some techniques of designing the system are also explained.

72-73:04A-062
DRIP IRRIGATION BIG SUCCESS AT BUENA VISTA WINERY,
Irrigation Journal, Vol. 22, No. 6, p 7-8, November-December, 1972. 3 fig.

Descriptors: *Irrigation practices, *Surface irrigation, Application equipment, Surface irrigation, Irrigation systems.

A description of a large drip irrigation system used at the Buena Vista Vineyards is given. The system seems to be very successful in supplying the needed water and also cuts both water use and cultivation costs.

72-73:04A-063
AUTOMATIC IRRIGATION SUPPLY SEQUENCING VALVE,
Cykler, J. F.
Mauna Kea Sugar Company, Hilo, Hawaii.
Agricultural Engineering, Vol. 53, No. 1, p 21, January, 1972. 2 fig.

Descriptors: *Irrigation practices, Surface irrigation, Sprinkler irrigation, Hydraulic valves, Automatic control.

This valve improves the man-day performance of irrigation crews handling a number of 1500 gpm automatic overhead irrigators. It is a primary directional flow control for a zone of irrigation where water could be switched to either of two quick-coupled or buried irrigation pipe lines. This valve assembly is self-contained with its own power supply and can be either portable or fixed. The assembly consists of a 6-inch DeZurik 3-way water valve fitted with a handle and a set screw to float the valve plug. The action of the valve, through its 90 degree arc of operation, is accomplished by a 4 inch by 12 inch double-acting hydraulic cylinder fitted with the usual swivel brackets and rod end clevises. The upstream water pressure provides the driving force to power the piston. A 100 mesh line filter prevents trash from plugging the small orifices in the solenoid water valves.

72-73:04A-064
IMPROVED INSTALLATION OF MICROTUBE DRIP IRRIGATION EMITTERS,
Wilke, O.
Texas A & M University, Agricultural Research and Extension Center, Lubbock.
Agricultural Engineering, Vol. 54, No. 5, p 17, May, 1973.

Descriptors: *Irrigation, Irrigation practices, Irrigation systems, Surface irrigation.
Identifiers: Drip irrigation.

Microtubes as drip irrigation emitters have several distinct advantages - low cost, good hydraulic characteristics, ease of installation. But if the wall of the microtube is thin, the tube may be pinched partially or totally closed where the tube is inserted into a hole punched in the irrigation lateral pipe. If the microtube is extended from the irrigation pipe, it may be cut by rabbits. As microtube emitter flows are increased, the water stream may travel several feet from the emitter. Foliage may be wetted. As the plastic irrigation pipe twists due to contraction, the stream direction may change, altering the soil area wetted by the emitter.

72-73:04A-065
SPRINKLER-INDUCED SOIL TEMPERATURE CHANGES UNDER PLANT COVER,
Kohl, R. A.
Snake River Conservation Research Center, Kimberly, Idaho.
Agronomy Journal, Vol. 65, No. 6, p 962-964, November-December, 1973. 5 fig, 1 tab, 8 ref.

Descriptors: *Irrigation practices, *Soil temperature, *Sprinkler irrigation, Potatoes, Surface irrigation, Irrigation practices, Irrigation design.

An experiment was conducted to determine the amount of soil temperature reduction to be expected from irrigating potatoes at various intervals. Soil temperatures were measured at the 10-cm depth under potato ridges with various amounts of plant cover. The mean daily soil temperature at the 10-cm depth in a silt loam soil after 7 days following irrigation increased as much as 2 C above the daily irrigated plot with full cover and 4 C above the daily irrigated plot without cover. Similar soil temperature increases occurred in a loamy fine sand soil irrigated after 5 days which is the normal irrigation intervals for these soils.

72-73:04A-066
USE OF SPRINKLERS TO STUDY THE INFLUENCE OF POPULATION DENSITY UPON SEED COTTON PRODUCTION IN AN ARID AREA,

Robinson, F. E., and Cudney, D.
California University, Department of Water Science and Engineering, Davis.
Agronomy Journal, Vol. 65, No. 2, p 266-268, March-April, 1973. 4 fig, 12 ref.

Descriptors: *Cotton, *Irrigation practices, *Sprinkler irrigation, Fertilizers, Plant populations, Crop response.

The growing period for cotton has been shortened by 2 months in the Imperial Valley because of an invasion by pink bollworm. The law now requires that cotton residue be incorporated into the soil early to lower the number of overwintering larvae. The shorter period for floral development led to reexamination of yield potential under different plant spacing. Defoliants, fertilizer, desiccants, and insecticides for pink bollworm control and water were applied through the sprinkler system. Randomized block designs of 'Stoneville 213' and 'Paymaster 111A' included plant densities of 15,000, 60,000, 242,000, and 969,000 plants/ha on a flat soil surface. Seeds were placed by hand at 2 per dibble in a square grid pattern. The bolls per plant were significantly affected by plant density. The effect of plant density on boll weight was significant on Paymaster 111A but not on the Stoneville 213. The highest seed cotton yield occurred where the plants produced the greatest number of bolls per hectare.

72-73:04A-067
OBJECTIVES OF IRRIGATION MANAGEMENT COMMITTEE,
Heermann, D. F.
United States Department of Agriculture, Agricultural Research Service, Fort Collins, Colorado.
Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 10 p, 53 ref.

Descriptors: Irrigation, Irrigation practices, Irrigation programs.

The Irrigation Group has reorganized and established a committee for Irrigation Management. The scope and objectives of the committee are presented. The interaction of the Irrigation Management Committee and other committees in the Society are discussed. The challenge for the new committee is to improve the management and operation of irrigation systems.

72-73:04A-068
OPTIMIZING SURFACE IRRIGATION UNIFORMITY BY NONUNIFORM SLOPES,
Powell, G. M., Jensen, M. E., and King, L. G.
CH/2 Hill, Redding, California
Presented at Winter Meeting of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 19 p, 6 fig, 22 ref.

Descriptors: *Irrigation, *Irrigation practices, Surface irrigation, Furrow irrigation, Irrigation design, Irrigation efficiency, Uniformity coefficient.

A mathematical computer model of surface irrigation was developed to consider nonuniform slopes and depth-dependent infiltration functions. The model is based on a predictor-corrector technique in which the advance for each time increment is predicted and the water surface profile computed. After computing surface and subsurface storage volumes, the predicted advance is adjusted by a volume balance correction procedure. The computation is fast and verification of the model with field data indicates the model is as accurate as measured input field parameters. The model was used to demonstrate the effect of slope profile on water distribution in furrow irrigation. A concave slope profile shows a significant improvement in water distribution over a uniform slope. A convex slope results in a significantly poorer distribution. The model can also be used to evaluate existing surface irrigated fields with uniform or nonuniform slopes.

72-73:04A-069
EVALUATION OF GRADED FURROW IRRIGATION WITH LENGTH OF RUN ON A CLAY LOAM SOIL,
Musick, J. T., Sletten, W. H., and Dusek, D. A.
Southwest Great Plains Research Center, Bushland, Texas
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 6, p 1075-1080, 1084, November-December, 1973. 11 fig, 1 tab, 13 ref.

Descriptors: *Irrigation practices, *Furrow irrigation, *Infiltration rates, Surface irrigation, Runoff, Infiltration, Inflow.
Identifiers: Graded furrows.

The effects of length of run on water intake, soil water distribution, grain sorghum yields and irrigation water use efficiencies were evaluated on graded furrow irrigated Pullman clay loam at Bushland, Texas, in 1961-63 on a 900-foot run and in 1965-66 on an 1,800-foot run. Total water intake during the 15 irrigations studied ranged from 1.3 to 6.0 inches, depending primarily on soil water content at time of irrigation and surface soil consolidation. Intake rates after runoff started were affected by length of run. As water advanced down the furrows, an increasing portion of the furrow length reached the basic rate which caused the average rate for the wetted furrow length to decline.

72-73:04A-070
TRICKLE IRRIGATION - APPLICATION UNIFORMITY FROM SIMPLE EMITTERS,
Bucks, D. A., and Myers, L. E.
United States Water Conservation Laboratory, Phoenix, Arizona.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 6, p 1108-1111, November-December, 1973. 4 fig, 3 tab, 12 ref.

Descriptors: *Irrigation practices, *Surface irrigation, Application equipment, Uniformity coefficient, Irrigation systems, Irrigation design.
Identifiers: Drip irrigation.

Procedures for design and construction of two multiple-size systems, using a stainless-steel and microtube or spaghetti-tube emitter, were developed. Mean discharge deviations for these simple emitters operated at constant pressure were from 1.7 percent to 3.3 percent for the stainless-steel emitters, and from 1.8 percent to 2.5 percent for the microtube emitters. Performance by a multiple-diameter stainless-steel emitter system designed for row-crop usage verified the practicality of changing emitter diameters along the lateral. The theoretical performance of a 250-foot lateral with a 2-foot emitter spacing, using five sizes of stainless-steel emitters, showed a mean deviation of 1.7 percent and maximum deviations of +5.2 percent to -6.6 percent from design discharge. Actual mean deviation from design discharge was 3.1 percent, with maximum deviations of +8.8 percent to -10.8 percent in the field.

72-73:04A-071
SKEWNESS AND KURTOSIS INFLUENCE ON UNIFORMITY COEFFICIENT, AND APPLICATION TO SPRINKLER IRRIGATION DESIGN,
Seniwongse, C., Wu, I., and Reynolds, W. N.
Hawaii University, Department of Agricultural Engineering.
Transactions of the American Society of Agricultural Engineers, Vol, 15, No. 2, p 266-271, March-April, 1972. 15 fig, 2 tab, 10 ref.

Descriptors: *Irrigation, *Irrigation practices, *Irrigation methods, Sprinkler irrigation, Uniformity coefficient.

Frequency analysis indicate that about 70 percent of sprinkler data, that portion of the data where the uniformity coefficients are 70 percent or greater, can be fitted by a gamma distribution. A preliminary study has shown that only a few low-uniformity sprinkler tests fit an exponential distribution. No sprinkler data were found to fit a poisson distribution. Skew and Kurtosis can be related to sprinkler uniformity coefficients with values of 70 percent or less. The distribution of low uniformity data is generally positively skewed.

72-73:04A-072
FURROW IRRIGATION FOR HAWAIIAN SUGARCANE,
Vaziri, C. M., Collins, H. G., and Reynolds, W. N.
Hawaiian Sugar Planters Association, Agricultural Engineering Experiment Station, Honolulu.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR1, p 1-14, March, 1973. 4 fig, 3 tab, 3 ref.

Descriptors: *Irrigation, *Irrigation practices, *Furrow irrigation, Hawaii, Hydraulics, Infiltration, Sugarcane, Water distribution (applied), Water control.

Empirical equations describing infiltration, advance, recession, and opportunity time for infiltration were developed by analysis of inflow-outflow-time measurements recorded during furrow irrigation of sugarcane. The measurements represent field conditions at various sugarcane ages on the Molokai soil series. A concept of relating furrow infiltration as a function of furrow length is presented. The development of equations and tables for use in the design and efficient operation of sugarcane furrow irrigation systems in the Hawaiian Islands is described.

72-73:04A-073
HYDRAULICS AND UNIFORMITY FOR DRIP IRRIGATION,
Wu, I. P., and Gitlin, H. M.
Hawaii University, Agricultural Engineering Department, Honolulu.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR2, p 157-168, June, 1973. 7 fig, 7 ref.

Descriptors: *Irrigation, *Irrigation practices, Surface irrigation, Irrigation efficiency, Irrigation systems, Pipe flow, Uniformity coefficient.
Identifiers: Drip irrigation, Pressure distribution.

A drip irrigation system consists of a main line, submains, and laterals and emitters. The flow condition in the submain and laterals is steady, spatially varied with lateral outflows; the discharge is decreasing with respect to the length of the line. By considering them as smooth pipes. Blasins equation for friction coefficient is used to determine energy drop between outlets along a drip irrigation line. The energy gradient line is not a straight line but a curve of exponential type which can be determined by calculating energy drop of all sections along the line. A simple way of estimating energy gradient line with only about 1% of error can be done by dividing the line into three or four segments and using the average discharge for each segment of calculate energy drops along the line. The pressure distribution along the line can be determined for both level and sloping surfaces.

72-73:04A-074
CENTER PIVOT PROBLEMS,
Irrigation Age, Vol. 6, No. 9, p 38-40, April, 1972. 1 tab.

Descriptors: *Irrigation practices, Surface irrigation, Sprinkler irrigation, Irrigation systems, Irrigation design, Application equipment.

The problems associated with center pivot sprinkler systems are outlined. Reasons for not using marginal land are explained. A chart for figuring your chances for success is presented.

72-73:04A-075
DETERMINATION OF WATER INTAKE RATE FROM RATE OF ADVANCE,
Singh, P., and Chauhan, H. S.
G. B. Pant University of Agriculture and Technology, Pantnagar, Nainital, India.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 6, p 1081-1084, November-December, 1973. 4 fig, 14 ref.

Descriptors: *Infiltration rates, *Soil, Infiltration, Infiltrometers, Moisture meters, Infiltration, Surface irrigation.

The relationship obtained is an attempt to improve existing methods for estimating intake rate in surface irrigation based on rate of water advance data. The comparison of the relationship with experimental data suggests that the cylinder in infiltrometers under-estimate intake rate at small values of time and over-estimate the intake rate at large values of time. The inflow-outflow method also may not represent actual intake rate because of errors due to surface storage. The method based on rate of water advance provides a good estimate of intake rate in surface irrigation.

72-73:04A-076
SPRINKLIGATION AS SEEN AND DONE BY THE OPERATOR,
Irrigation Age, Vol. 6, No. 6, p 10-24, January, 1972. 12 fig.

Descriptors: *Irrigation practices, Surface irrigation, Sprinkler irrigation, Irrigation systems, Irrigation design, Application equipment.

The field of sprinkler irrigation is reviewed. The various types of systems are discussed including: hand move, solid set, wheel move, and center pivot systems. The importance of proper management is stressed.

72-73:04A-077
DRIP, DRIP, DRIP, DRIP, DRIP,
Irrigation Age, Vol. 6, No. 7, p 14-16, 39-40, February, 1972.

Descriptors: *Irrigation practices, *Irrigation systems, Surface irrigation, Irrigation, Irrigation design.

A revolutionary new development in irrigation developed and perfected in Israel, will be introduced on a major scale in the United States. Mr. Symcha Blass of Tel Aviv, originator of trickle-root irrigation widely utilized in Israel and the Netafim Drip Irrigation firm, its manufacturer, signed a licensing agreement in September with industrialist Howard Klein of Washington, D. C., who heads an agro-technical organization formed to install this system throughout the United States.

72-73:04A-078
MORE PRODUCTION...FEWER IRRIGATIONS,
Milligan, T.
Irrigation Age, Vol. 6, No. 12, p 20, 21, 26, 27, July, 1972. 1 fig, 1 tab.

Descriptors: *Irrigation practices, *Irrigation programs, Soil moisture, Crop response, Irrigation systems, Surface irrigation.

Briefly describes irrigation activities in non-technical terms. Approximate figures for peak water use by various crops are given by climate.

72-73:04A-079
PRELIMINARY OBSERVATIONS ON THE USE OF FERTIGATION...NEBRASKA STYLE,
Volk, R. R.
Irrigation Age, Vol. 6, No. 8, p 28-29, 32, March, 1972. 1 fig, 1 tab.

Descriptors: *Fertilization, *Application methods, Crop response, Corn, Irrigation, Timing, Farm management.

A study of present forms of fertilizer application vs. "fertigation" was carried out at the University of Nebraska Mead Field Laboratory in the summer of 1971 on a silty clay loam soil. The study compared sidedress and irrigation water applied nitrogen solution. All plots received equal amounts of water and were planted to the same hybrid corn. Sprinkler applied nitrogen was uniformly extracted throughout the soil profile by the corn plants in all treatments. The check had the highest amount of nitrates removed at the four feet depth. This means the corn was in need of more nitrogen and the amount of starter supplied was not sufficient. The study did not differentiate yield differences between sidedress and irrigation water applied nitrogen.

72-73:04A-080
DO I REALLY NEED TO IRRIGATE TODAY,
Davis, C. H.
Irrigation Age, Vol. 6, No. 7, p 61-62, 64, February, 1972. 1 fig.

Descriptors: *Irrigation practices, *Soil moisture, Crop response, Irrigation, Irrigation design, Timing.

A non-technical method for determining when to irrigate is presented. The method is based on average soil moisture holding capacity for soil types. The moisture content is determined using electronic soil moisture probes.

72-73:04A-081
KNOW YOUR SPRINKLER APPLICATION RATES,
New, L.
Texas Agricultural Extension Service.
Irrigation Age, Vol. 6, No. 6, p 58-59, 62-63, 66-69, January, 1972. 1 fig, 3 tab.

Descriptors: *Irrigation practices, *Surface irrigation, Sprinkler irrigation, Irrigation systems, Application equipment, Application methods, Rates of application.

A method for determining sprinkler application rates is presented. The method is designed for use by non-technical personnel. Tables are given for ease of application. Detailed examples are provided.

72-73:04A-082
GUIDELINES FOR SUCCESSFUL CENTER-PIVOT IRRIGATION,
Miller, M.
Irrigation Age, Vol. 6, No. 6, p 8, 76-77, January, 1972. 2 fig.

Descriptors: *Irrigation practices, Surface irrigation, Sprinkler irrigation, Irrigation systems, Irrigation design.

A summary of the factors necessary for successful operation of a center-pivot sprinkler system is presented. A list of Do's and Don'ts has been developed. A state-of-the-art summary is included.

72-73:04A-083
GATED PIPE AND REUSE SYSTEM,
Irrigation Age, Vol. 6, No. 9, p 18-19, 45, April, 1972. 2 fig.

Descriptors: *Irrigation practices, Surface irrigation, Furrow irrigation, Irrigation systems, Irrigation design.

The layout of a 160-acre farm irrigation system using gated pipe and a tail-water reuse system is presented.

72-73:04A-084
IRRIGATION, DRAINAGE AND SALINITY
UNESCO/FAO
Hutchinson and Company (Publishers) Ltd. 3 Fitzroy Square, London W1. 1973. 510 p.

Descriptors: *Irrigation, Irrigation effects, Irrigation water, *Drainage, Salt balance, Saline soils, Saline water, *Salinity, Soil chemistry.

Throughout history, irrigation in arid zones has often led to soil salinization, thereby creating a problem which has faced man for centuries. With the increase of the world's population and the rapid development of irrigated areas, this question becomes more and more urgent. Not only must unproductive lands be placed under cultivation, but the productivity of irrigated areas must also be maintained. The experience gained in recent decades, along with a considerable amount of research which has been conducted regarding irrigation, drainage, and salinity, have produced a great variety of data. This book is a compendium of material prepared by numerous investigators throughout the world. The book not only covers the development of scientific knowledge, but also provides practical guidelines for field solutions.

72-73:04A-085
ARID ZONE IRRIGATION,
Yaron, B., Danfors, E., and Vaadia, Y.
Springer-Verlag, New York, Heidelberg, Berlin. 1973. 434 p.

Descriptors: *Arid lands, *Irrigation, *Irrigation practices, Salinity, Salt balance, Soil chemistry, Soil physics, *Soil-water-plant relationships, *Water requirements.

This book has been written for agronomists, soil scientists, water engineers and plant physiologists who want a clear presentation of irrigation fundamentals in arid and semi-arid zones. This treatise provides an understanding of the basic principles governing irrigation technology and helps to overcome the problem of water shortage in arid zone agriculture. This book, written by a large numer of specialists and covering a broad spectrum of different disciplines, is a synthesis of general up-to-date information, and the results of the author's own research. The book covers such topics as water resources, soil-water-plant relationships, chemistry of irrigated soils, field investigations, soil and water salinity, irrigation practices and crop water requirements.

Section XIX

WATER QUANTITY MANAGEMENT AND CONTROL

GROUNDWATER MANAGEMENT (Group 04B)

72-73:04B-001
SELECTED METHODS OF AQUIFER TEST ANALYSIS,
Schicht, R. J.
Illinois State Water Survey, Urbana.
Water Resources Bulletin, Vol. 8, No. 1, p 175-187, February 1972. 8 fig, 27 ref.

Descriptors: *Aquifer characteristics, *Analytical techniques, *Hydrogeology, Pumping, Transmissivity, Permeability, Water yield, Drawdown, Storage coefficient, Confined water, Water table.
Identifiers: *Aquifer testing, Aquifer evaluation, Pumping tests.

Changes in groundwater levels due to a well discharging at a constant rate are used with various formulas to determine hydraulic properties of aquifers and their confining bed and to detect the presence of aquifer boundaries. These formulas are generally solved by graphical methods. Graphs of drawdown versus time after pumping started, and/or drawdown versus distance from the pumped well, are used to solve formulas which express the relation between the hydraulic properties of an aquifer and its confining bed and the lowering of water levels in the vicinity of a pumped well. The principal hydraulic properties are aquifer transmissivity, the coefficient of storage, and the vertical permeability of the confining bed. Aquifer pumping test procedures are described; also methods of aquifer tests analysis presently being used by the Illinois State Water Survey.

72-73:04B-002
SALTWATER INTRUSION INTO AQUIFERS,
Bruington, A. E.
Los Angelos County Flood Control District, California.
Water Resources Bulletin, Vol. 8, No. 1, p 150-160, February 1972. 11 fig.

Descriptors: *Saline water intrusion, *Aquifers, *Hydrogeology, Withdrawal, Water levels, Groundwater movement, Injection wells, Water pollution sources, Brines, Saline water systems, Reviews, History.

Salt-water intrusion into fresh groundwater aquifers is common throughout the United States. There are three mechanisms by which intrusion occurs. One is the reversal or reduction of groundwater gradients, which allows saline water to move. A second is through the destruction of natural barriers that formerly prevented the movement of salt waters or separated bodies of fresh and salt water. The third is the improper disposal of waste saline water. One solution to the problem is the pressure barrier system used in Los Angelos County, where a line of injection wells was installed parallel to the seacoast. Fresh water is injected into these wells under pressure so that a pressure barrier is formed high enough to control intruding sea water. The pumping barrier is a line of pumping wells between the source of intrusion and the inland pumping fields. These wells are pumped at a rate which will cause a groundwater pressure trough to be formed along the line of wells low enough so that sea water cannot pass inland. Since the problem usually stems from over pumping, a program of reduced pumping can be developed. Another way is to continue pumping in the historical pattern but increase the available groundwater supply by recharge.

72-73:04B-003
GROUNDWATER RECHARGE,
Brown, R. F. and Signor, D. C.
Water Resources Bulletin, Vol. 8, No. 1, p 132-149, February 1972. 1 fig, 1 tab, 40 ref.

Descriptors: *Artificial recharge, *Texas, *Groundwater recharge, Water spreading, Recharge wells, Pit recharge, Recharge, Water storage, Water quality, Hydrogeology, Water resources development.

An evaluation of current knowledge of processes and problems of artificial recharge indicates that a great deal of additional research is necessary before recharge feasibility can be evaluated in most situations. Experience in using recharge wells on the Southern High Plains of New Mexico and Texas yields predictions of success when using good quality water, and failure when recharge water contains high concentrations of particulate matter. Surface spreading is a more suitable method when water has a high sediment content, but may not be feasible in some hydrogeologic situations. Theoretically, well construction should be important to the success of injection recharge operations, but little experimental work exists to support this view. Results of recharge experiments on the Southern High Plains are reviewed.

72-73:04B-004
COMBINED SURFACE WATER-GROUNDWATER ANALYSIS OF HYDROLOGICAL SYSTEMS WITH THE AID OF THE HYBRID COMPUTER,
Morris, W. J., Morgan, N. W., Wang, B. H., and Riley, J. P.
Utah Water Research Laboratory, Logan.
Water Resources Bulletin, Vol. 8, No. 1, p 63-76, February 1972. 13 fig, 3 tab, 4 ref.

Descriptors: *Conjunctive use, *Surface-groundwater relationships, *Irrigation design, *Water balance, *Computer programs, Evapotranspiration, Digital computers, Analog computers, Computer models.
Identifiers: *Hybrid computers.

The partial and total differential equations for an integrated surface water-groundwater system may be solved using a hybrid computer. The computing technique makes a rapid and accurate study of the groundwater response due to varying inputs (deep percolation) or outputs (evapotranspiration) from the groundwater system. Spatial variations in basic vegetation phenomena, such as pattern, and hydrological parameters, are represented by means of a grid network which also allows the input of variable boundary conditions. The model is applied to an area in South America which is subject to high water-table conditions. Various reclamation schemes and management practices under conditions of irrigated agriculture are assessed.

72-73:04B-005
GROUNDWATER MANAGEMENT ON THE TEXAS HIGH PLAINS,
Jones, O. R., and Schneider, A. D.
Southwestern Great Plains Research Center, Bushland, Texas

Water Resources Bulletin, Vol. 8, No. 3, p 516-522, June, 1972. 3 fig, 1 tab, 16 ref.

Descriptors: *Water management (Applied), *Texas, *Groundwater, *Water quality control, *Conjuctive use, Water reuse, Return flow, Irrigation water, Irrigation operation and maintenance, Irrigation practices, Water conservation.
Identifiers: Ogallala aquifer (Texas).

The effects of major water management practices on the pumping requirement from the Ogallala aquifer are discussed. Demand on the aquifer may be reduced as much as 15% by recycling irrigation runoff, 25% by recycling irrigation runoff and irrigating with water from playas, and 29% by recycling irrigation water in combination with irrigation from playas and artificial recharge of playa water to the aquifer. Other practices that can result in more efficient use of precipitation and groundwater are limited irrigation, land forming, soil profile modification, and improved irrigation systems, thereby reducing the pumping demand on the Ogallala. Additional water supplies can be obtained by water harvesting, weather modification, and water importation. The overdraft on the aquifer can be reduced by the application of sound water management practices on an area-wide basis.

72-73:04B-006
NONSTEADY FLOW TO A WELL WITH TIME DEPENDENT DRAWDOWN,
Williams, R. A., Lai, R. Y. and Karadi, G. M.
Wisconsin University, Milwaukee, Department of Civil Engineering.
Water Resources Bulletin, Vol. 8, No. 2, p 294-303, April 1972. 6 fig 7 ref.

Descriptors: *Groundwater movement, *Unsteady flow, *Artesian aquifers. *Drawdown, Water yield, Transmissivity, Aquifer characteristics, Mathematical studies, Water levels, Water table, Aquifer testing, Specific capacity, Confined water.

Confined flow toward a single well or finite radius in an extensive aquifer of uniform transmissibility was studied under the assumption of time-dependent drawdown. Three particular cases were considered: (a) linear drawdown (including constant drawdown; (b) exponential drawdown; (c) periodic (sinusoidal) drawdown. The differential equation governing unsteady axial symmetric flow toward a single well in a confined aquifer was solved for the three different situations by the use of the Laplace transform method. The resulting expressions are integrated by adapting a modified Germant scheme. General computer programs were developed and operated for several combinations of characteristics. The results were plotted to show the effect of time dependent drawdown on the variation of the well discharge and the piezometric head distribution.

72-73:04B-007
STREAM DEPLETION BY WELLS IN THE SOUTH PLATTE BASIN--COLORADO,
Danielson, J. A., and Qazi, A. R.
Colorado Division of Water Resources, Denver,
Water Resources Bulletin, Vol. 8, No. 2, p 359-366, April 1972. 5 fig, 1 tab, 3 ref.

Descriptors: *Conjunctive use, *Colorado, *Return flow, *Surface-groundwater relationships, *Irrigation wells, Irrigation water, Alluvium, Base flow, Water rights, Prior appropriation.
Identifiers: *South Platte Basin (Colorado).

Drought conditions combined with improved well technology resulted in a large amount of well development in the South Platte valley of Colorado during the period 1952-56. These wells were used for supplemental supply in many cases, but the application of sprinkler irrigation brought many acres of dry land into irrigated production. As a result of the groundwater withdrawal, senior surface appropriators found a decreasing amount of water available in the streams. The legislature, observing the doctrine of prior appropriation, ruled that all surface and groundwater in a tributary would be treated and administered as one resource. Analysis of a segment of the river was made with careful determination of all inflow and outflow in the study reach to include correlations required to determine ungaged side-channel inflow and unmetered irrigation wells. Wells have intercepted normal return flows to the river resulting in a decreased amount of surface water during the irrigation season. Stream depletion appears to equal the expected consumptive use of well water which ranged between 40% to 50% of the groundwater extraction.

72-73:04B-008
SOIL HYDROLOGY IN A SEMIARID WATERSHED,
Nixon, P. R., Lawless, G. P., and McCormick, R. L.
Agricultural Research Service, Weslaco, Texas
American Society of Agricultural Engineers, Transactions, Vol. 15, No. 5,
p 985-991, 1972. 6 fig, 3 tab, 12 ref.

Descriptors: *Soil investigations, *Soil moisture, *Soil-water-plant relationships, *Groundwater recharge, *Soil moisture meters, *Soil water movement, Hydrology, Arid lands, Watershed management, Soil management, Water yield improvement, Brush control, Soil profiles, *California, Chaparral, Precipitation (Atmospheric), Infiltration, Percolation, Root zone, Unsaturated flow, Moisture availability.

Soil hydrology studies in central coastal California (near Lompoc) indicate that groundwater recharge occurs from on-site precipitation. Changes and redistributions of moisture in deep sandy profiles at four naturally vegetated upland sites were studied. Following the summer dry season, the winter rain water penetrates as a wetting front. This water does not reach the bottom of the root zone every year; hence, recharge is intermittent. During a 10-year study, the water-year precipitation ranged from 7 to 31 inches at four sites. The resulting penetration of rain water ranged from 2.5 to more than 19 feet, the maximum depth of sampling. Natural recharge occurred once under chamise brush (Adenostoma fasciculatum), twice under coastal live oak (Quercus agrifolia) three times under grass-weed, and four times under a canyon oak thicket (Quercus wislinzenii). Variations are mainly due to precipitation, soil, and climate characteristics rather than vegetation type at the various sites. Extrapolation of the results at these four sites suggests that a typical naturally vegetated site in the sandy area contributes to recharge on the average of once every 7 years. Conversion of vegetation from brush and trees to grass is felt to be of questionable value in increasing water yields in this low rainfall area.

72-73:04B-009
ECONOMIC OPTIMIZATION OF A SINGLE-CELL AQUIFER,
Brown, G., Jr., and Deacon, R.
Washington University, Seattle, Department of Economics.
Water Resources Research, Vol. 8, No. 3, p 557-564, June, 1972. 3 fig 12 ref.

Descriptors: *Water quality, *Water treatment, *Aquifers, Surface waters,

Artificial recharge, Water table, Algorithms, Mathematical models, Optimization, Net profit, Systems analysis, Groundwater availability, Surface water availability.
Identifiers: Groundwater management, Groundwater withdrawal, Groundwater consumption, Pumping tax, Lift levels.

Optimal economic use of an aquifer of over time is analyzed under conditions of economic growth, inequality of groundwater withdrawal and consumption, and availability of surface water and artificial recharge; the value of an aquifer as a natural water quality treatment facility is derived. These conditions are discussed in depth and presented explicitly as four subject areas that have hitherto remained unexplored. The stage is set with a simple nonstochastic groundwater model using optimal control; equations are plentiful throughout the study. Discussed are optimal life levels and pumping tax for a groundwater basin characterized by simple growth of the net benefits of water. Second, the model makes explicit the important distinction between groundwater use and consumption: Groundwater users with different rates of return flow should pay different pumping tax rates because they borrow different amounts of capital. Third, it is shown that introducing surface waters or artificial recharge replenishment raises the water table and lowers the pumping tax. And fourth, an explicit distinction is made between water quantity and water quality that permits the determination of the value of a groundwater basin as a natural water quality treatment facility.

72-73:04B-010
DIGITAL COMPUTER SIMULATION FOR SOLVING MANAGEMENT PROBLEMS OF CONJUNCTIVE GROUNDWATER AND SURFACE WATER SYSTEMS,
Young, R. A., and Bredehoeft, J. D.
Resources for the Future, Incorporated, Washington, D. C.
Water Resources Research, Vol. 8, No. 3, p 533-556, June 1972. 10 fig, 8 tab, 37 ref.

Descriptors: *Conjunctive use, *Surface-groundwater relationships, *Simulation analysis, *Water management (Applied), Mathematical models, Optimum development plan Water resources development Hydrogeology, Stochastic processes.
Identifiers: South Platte River (Colorado).

In river basins where aquifers are intimately associated with streams, the unrestricted development of groundwater can reduce streamflows and jeopardize the rights to the flow of surface water. A simulation model was developed to aid in the solution of such problems. The model is composed of (1) a hydrologic model that represents the physical response of the stream-aquifer system to changes in river flows, diversions, and pumping, and treats streamflow as a stochastic input and (2) an economic model that represents the response of irrigation water users to variations in water supply and cost. These elements were incorporated into a decision framework so that the net income to the water resource system associated with alternative management schemes could be measured. The results of operating the model with parameters representing conditions in the South Platte Valley of eastern Colorado under alternative institutional and hydrologic conditions are reported.

72-73:04B-011
PUMPING AN ARTESIAN SOURCE FOR WATER TABLE CONTROL,
Doering, E. J., and Benz, L. C.
Agricultural Research Service, Mandan, North Dakota, Soil and Water Conserva-

tion Research Division.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR2, Paper 8964, p 275-287, June 1972. 8 fig, 23 ref.

Descriptors: *Drainage programs, *Pumping, *Artesian aquifers, *Water levels, *North Dakota, Aquifer testing, Hydrogeology, Water table, Leaching, Confined water, Drawdown.
Identifiers: *Red River Valley (N Dakota).

Pumping of an artesian aquifer in the Red River Valley of North Dakota can be used to control the water table in the overlying waterlogged and saline agricultural lands at an estimated pumping cost of $0.34 per acre per year. Because the fine-textured overburden is more than 100 ft thick and has a very low vertical hydraulic conductivity, continuous pumping will be necessary. By reducing the artesian pressure, the upward flow of saline water will be stopped, the water table in the leaky overburden will be reestablished at a greater depth, and salts can be leached from the root zone by precipitation. Even though the water pumped from the artesian aquifer is saline, the amount would be small enough that its discharge into the Red River of the North at low flow would not make the river water unsuitable for domestic use.

72-73:04B-012
WATER TABLE DRAWDOWN DUE TO A PUMPED WELL IN AN UNCONFINED AQUIFER,
Streltsova, T. D., and Rushton, K. R.
Birmingham University (England). Department of Civil Engineering,
Water Resources Research, Vol. 9, No. 1, p 236-242, February 1973. 4 fig, 2 tab, 4 ref.

Descriptors: *Groundwater movement, *Drawdown, *Withdrawal, *Unsteady flow, *Aquifer testing, Water level fluctuations, Water yield, Saturated flow, Unsaturated flow, Percolation, Capillary fringe, Capillary water, Drainage.

A general solution of the water table drawdown for unsteady radial flow to a pumped well is considered. Tabulated values for the free surface function are calculated for the range of parameters occurring in practical situations. A comparison with the available solution of Boulton is made, an appraisal of the assumptions being introduced in the derivation of the solutions. A numerical example of unsteady radial flow in an unconfined aquifer with details of the main part of the computer program is presented.

72-73:04B-013
FLOW NEAR A PUMPED WELL IN AN UNCONFINED AQUIFER UNDER NONSTEADY CONDITIONS,
Streltsova, T. D.
Birmingham University, (England), Department of Civil Engineering.
Water Resources Research, Vol. 9, No. 1, p 227-235, February 1973. 5 fig, 1 tab, 10 ref.

Descriptors: *Groundwater movement, *Drawdown, *Withdrawal, *Unsteady flow, *Aquifer testing, Water level fluctuations, Water yield, Saturated flow, Unsaturated flow. Percolation, Capillary fringe, Capillary water, Drainage.

The problem of unsteady radial flow in an unconfined aquifer is considered as a boundary value problem with discontinuous initial conditions at the surface of the well. The discontinuity of heads occurs at the surface of the well as pumping commences; it dies down in time exponentially and this represents the delay of the transitional process of reestablishing equilibrium in time. The downward variable movement of water in the vicinity of the well resulting from this discontinuity is proportional to the difference between the gradually falling water table and the average head and is a cause of the slow draining of the unconfined aquifer. The contribution of the unsaturated zone of the aquifer in the process of slow drainage is usually of minor importance and subordinate as far as most drainage problems are concerned. Experimental verification and model design are presented.

72-73:04B-014
TRANSIENT FLOW TO FINITE WELL IN UNCONFINED AQUIFER,
Clever, R. M., Catton, I., and Perrine, R. L.
California University, Los Angelos, School of Engineering and Applied Science.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY3, Paper 9611, p 485-494, March 1973. 7 fig, 5 ref.

Descriptors: *Unsteady flow, *Groundwater movement, *Water table, *Equations, Water yield, Drawdown, Withdrawal, Numerical analysis, Water wells, Mathematical studies.

The problem of nonsteady radial flow toward a finite well in an unconfined aquifer is solved by a form of the Galerkin method. The equations are reduced to a set of coupled nonlinear ordinary differential equations in the time-dependent Galerkin coefficients, with a constraint equation due to the nonlinear well bore boundary condition. These are solved numerically by the Adams method for a range of forcing. An eight term approximation proves sufficient to yield good results for the trial functions used. Where comparison is possible, there is good agreement with other results and other solution methods. Response of the flow system depends strongly on the parameters characterizing the aquifer. Time to maximum drawdown at the well is very sensitive to production rate and well radius. A similarity transformation for this problem, with a singularity at r±0, frequently appears. Retransformation to remove the singularity yields a more thorough understanding of the range of validity of the solution.

72-73:04B-015
UNSTEADY FLOW TOWARD AN ARTESIAN WELL,
Huang, Y. H.
Kentucky University, Lexington, Department of Civil Engineering.
Water Resources Research, Vol. 9, No. 2, p 426-433, April 1973. 6 fig, 1 tab, 7 ref.

Descriptors: *Finite element analysis, *Unsteady flow, *Artesian wells, *Drawdown, Hydraulic models, Computer programs, Groundwater movement, Artesian aquifers.

Unsteady drawdown around an artesian well may be calculated using a finite element method programmed for a high-speed computer. On the basis of assumptions that the well has a finite radius and that the discharge from a partially penetrating well is not uniform along the well bore, numerical solutions for various well penetrations are presented and compared with the experimental measurements from a sand model. The numerical solutions check reasonably with the experimental measurements.

72-73:04B-016
ANALYSIS OF SEEPAGE INTO GROUNDWATER SYSTEM,
Abiodun, A. A.
Ife University (Nigeria), Department of Agricultural Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY7, p 1203-1208, July 1973. 8 fig, 7 ref, append.

Descriptors: *Seepage, *Recharge, *Groundwater movement, Infiltration, Canal seepage, Artificial recharge.

Analytical methods were developed to simulate seepage into a groundwater system from a range of geometries. The solutions to such problems might find practical application in situations where subsurface lateral distribution of seepage flows is to be restricted and also in cases where porous medium that is to be replenished is overlain by a fairly thin impermeable layer. The particular case chosen is that of seepage through a channel with impervious side walls and permeable bottom. The driving force of the flow system is the force of gravity and the flow is two-dimensional. The seepage flows are steady and fully saturated, taking place in an isotropic, homogeneous, porous medium, and Darcy's Law is applicable. The solution to this problem was obtained through the application of the hodograph technique.

72-73:04B-017
PERFORMANCE OF A TILE DRAINAGE SYSTEM: AN EVALUATION OF A TILE DESIGN AND MANAGEMENT,
Perrier, E. R., MacKenzie, A. J., Grass, L. B., and Shull, H. H.
United States Department of Agriculture, Urbana, Illinois.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 440-444, May-June, 1972. 6 fig, 6 tab, 15 ref.
(See 72-73:02G-030)

72-73:04B-018
CAPILLARY PROPERTIES OF SOILS - INFLUENCE UPON SPECIFIC YIELD,
Duke, H. R.
United States Department of Agriculture, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 4, p 6880691, July-August, 1972. 6 fig, 2 tab, 9 ref.
(See 72-73:02F-061)

72-73:04B-019
APPLICATION OF MONTE CARLO METHOD TO SOIL WATER MOVEMENT,
Shih, S. F., and Kriz, G. J.
North Carolina State University, Raleigh.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 897-901. September-October, 1972. 5 fig, 4 tab, 8 ref.
(See 72-73:02G-040)

72-73:04B-020
WATER-MANAGEMENT PROBLEMS RELATED TO GROUNDWATER RIGHTS IN THE SOUTHWEST,
Thomas, H. E.
United States Geological Survey, Menlow Park, California.

Water Resources Bulletin, Vol. 8, No. 1, p 110-117, February, 1972. 27 ref.

Descriptors: *Water law, *Water rights, *Groundwater, Conjunctive use, Groundwater availability, Groundwater resources, Water supply, Water utilization, Texas, New Mexico, Arizona, California.

Brief summaries of the systems of underground water rights for the states of Texas, Arizona, New Mexico and California are presented. Numerous references on the subject are listed.

72-73:04B-021
MEASUREMENT OF UNSATURATED HYDRAULIC CONDUCTIVITY BY THE CONSTANT OUTFLOW METHOD,
Overman, A. R., and West, H. M.
Florida University, Gainesville.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 6, p 1110-1111, November-December, 1972. 6 fig, 4 ref.
(See 72-73:02G-042)

72-73:04B-022
WATER TABLE AND SOIL MOISTURE PROBABILITIES WITH TILE DRAINAGE,
Young, T. C., and Ligon, J. T.
Clemson University, Clemson, South Carolina.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 448-451, May-June, 1972. 8 fig, 13 ref.
(See 72-73:02G-043)

72-73:04B-023
TENSIOMETER-PRESSURE TRANSDUCER SYSTEM FOR STUDYING UNSTEADY FLOW THROUGH SOILS,
Fitzsimmons, D. W., and Young, N. C.
Idaho University, Moscow.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 272-275, March-April, 1972. 6 fig, 10 ref.
(See 72-73:02G-045)

72-73:04B-024
MODELLING A GROUNDWATER AQUIFER IN THE GRAND PRAIRIE OF ARKANSAS,
Griffis, C. L.
Arkansas University, Fayetteville.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 261-263, March-April, 1972. 6 fig, 5 ref.
(See 72-73:02F-006)

72-73:04B-025
TENSIOMETER USE IN SHALLOW GROUND-WATER STUDIES,
Richards, S. J., Willardson, L. S., Davis, S., and Spencer, J. R.
Soil Physicist, Riverside, California.
Journal of the Irrigation and Drainage Division, American Society of Civil

Engineers, Vol. 99, No. IR4, p 457-464, December, 1973. 7 fig, 7 ref.
(See 72-73:02F-068)

72-73:04B-026
SIMULATION OF POST-IRRIGATION MOISTURE MOVEMENT,
Molz, F. J.
Auburn University, Auburn, Alabama.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR4, p 523-532, December, 1972. 9 fig, 1 tab, 12 ref.
(See 72-73:02G-071)

72-73:04B-027
PREFABRICATED FILTER-FIN FOR SUBSURFACE DRAINS,
Healy, K. A., and Long, R. P.
Connecticut University, Storrs.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR4, p 543-552, December, 1972. 5 fig, 1 tab, 5 ref.
(See 72-73:02G-072)

72-73:04B-028
SOLUTIONS FOR LATERAL OUTFLOW IN PERFORATED CONDUITS,
Berlamont, J., and Van der Beken, A.
State University of Ghent, Department of Civil Engineering, Ghent, Belgium.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No. HY9, p 1531-1549, September, 1973. 11 fig, 3 tab, 17 ref.
(See 72-73:04A-037)

72-73:04B-029
UNSTEADY FLOW TO BOTTOM DRAIN IN BOUNDED AQUIFER,
Krizek, R. J., Soriano, A., and Gyuk, I.
Northwestern University, Evanston, Illinois.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 99, No. IR2, p 169-182, June, 1973. 6 fig, 11 ref.
(See 72-73:02F-079)

72-73:04B-030
SALINIZATION OF GROUNDWATER IN ARID ZONES,
Barica, J.
Fisheries Research Board of Canada, Winnipeg (Manitoba), Freshwater Institute.
Water Research, Vol. 6, No. 8, p 925-933, August, 1972. 6 fig, 3 tab, 13 ref.

Descriptors: *Water pollution, *Saltation, *Ion transport, *Water quality, *Saline water intrusion, *Saline water-freshwater interfaces, Saline water, Groundwater, Arid lands, Environmental effects, Irrigation effects, Groundwater recharge, Salinity, Salts.
Identifiers: Middle East.

Natural pollution of surface and groundwaters by inorganic salts (mostly chlorides and sulphates of Na, Mg and Ca) in arid zones is a consequence of the dry climate and the extensive irrigation practices in agriculture. Salts, accumulated in the soil profile after evaporation of the water phase, are redissolved either by fluctuation of shallow groundwater or leached down by fresh irrigation water applied on the soil surface. This results in a continuous increase in groundwater salinity and deterioration of its quality. Two specific cases, typical of arid regions in the Middle East, are considered: (l) shallow groundwaters of extremely high water tables (0.5-2.0 m) in alluviums of large rivers (Tigris and Ephrates), and (b) deeper groundwaters (5-16 m) in desert areas with nonsaline sandy soils of high permeability (Saudi Arabian Plateau). In alluvial regions, groundwaters with a total dissolved solids concentration as high as 46,000 mg/l can be found. In desert oasis areas, layering of relatively fresh water (TDS 500-3500 mg/l) above the saline groundwater (TDS 7000-12,000 mg/l) can occur. Vertical distribution of groundwater quality within the same aquifer shows pronounced zonation. Methods of water salination control and utilization of saline water resources to supplement the existing water supplies in arid countries are discussed.

Section XX

WATER QUANTITY MANAGEMENT AND CONTROL

EFFECTS ON WATER OF MAN'S NON-WATER ACTIVITIES (Group 04C)

72-73:04C-001
SALTS IN IRRIGATION DRAINAGE WATERS: I. EFFECTS OF IRRIGATION WATER COMPOSITION, LEACHING FRACTION, AND TIME YEAR ON THE SALT COMPOSITIONS OF IRRIGATION DRAINAGE WATERS,
Rhoades, J. D., Ingvalson, R. D., Tucker, J. M., and Clark, M.
Agricultural Research Service, Riverside, California, Salinity Laboratory.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 770-774, September-October 1973. 6 tab, 13 ref.

Descriptors: *Leaching, *Return flow, *Water pollution sources, Lysimeters, Water quality, Water chemistry, Salts, Alfalfa, Irrigation practices, Soil chemistry.

The compositions of percolated drainage waters resulting from the use of eight synthetic river waters of the Western USA under alfalfa production in a controlled lysimeter experiment were studied. The compositions are affected by the composition of the river water used for irrigation, the fraction of applied water that appeared as drainage water, the presence or absence of soil CaCO3, whether or not the drainage water is open to the atmosphere, and the time of year.

Section XXI

WATER QUANTITY MANAGEMENT AND CONTROL

WATERSHED PROTECTION (Group 04D)

72-73:04D-001
WATERSHED MANAGEMENT: A SYSTEMS APPROACH,
Eisel, L. M.
Harvard University, Cambridge, Massachusetts, Division of Engineering and Applied Physics.
Water Resources Research, Vol. 8, No. 2, p 326-338, April 1972. 6 fig, 2 tab, 19 ref.

Descriptors: *Watershed management, *Irrigation water, *Environmental control, *Decision making, *Systems analysis, Mathematical models, Stochastic processes, Recreation demand, Forest management, Range management, Risks, Hydrologic cycle, Streamflow, Surface runoff, River flow, Sedimentation, Reservoir, Ecosystems, Wildlife.
Identifiers: *Water resource system, Chance constraints, Wildlands, Western United States.

A systems approach is developed to determine the type and extent of land use management activities in wildland areas. A chance constrained programming model is applied to a hypothetical watershed in order to investigate the effects of risk and uncertainty on land use management decisions. The model solution indicates that risk and uncertainty associated with the system of physical and economic parameters can significantly affect land use management policy-making. The solution also indicates that forest management practices to increase streamflows may have only a minimal effect on the design and operation of downstream reservoirs, and that future outdoor recreational demand and benefits are important factors to consider in the arrangement of land use management activities.

72-73:04D-002
INFILTRATION, HYDRAULIC CONDUCTIVITY, AND RESISTANCE TO WATER-DROP IMPACT OF CLOD BEDS AS AFFECTED BY CHEMICAL TREATMENT,
Gabriels, D. M., Moldenhauer, W. C., and Kirkham, D.
Iowa State University, Ames, Department of Soil Science.
Soil Science Society of America Proceedings, Vol. 37, No. 4, p 634-637, July-August 1973. 4 tab, 15 ref.

Descriptors: *Infiltration, *Soil erosion, *Impact (Rainfall), *Erosion control, *Soil treatment, Soil structure, Soil sealants, Soil stability, Water proofing, Wetting, Wettability.
Identifiers: Soil conditioners.

To test the effectiveness of surface treatments in preventing erosion during rainfall, chemicals and bitumen were sprayed on large dry surface clods (8 to 20 mm) and small surface clods (2 to 8 mm) of a Clarion loam. The small clods were initially wetted with 15% water on a soil weight basis and mixed with bitumen emulsions. The large and small clods were subjected to a 6.35-cm-per-hour simulated rainfall. Simultaneously with the measurements of infiltration rate, determinations were made of the starting time for initial runoff, energy needed to initiate runoff, runoff rate, total soil loss, and final soil loss rate. Most of the soil conditioners on large clods kept the infiltration rate high and prevented runoff on a 9% slope. Polyvinyl alcohol and polyacrylamide prevented any soil loss during 90 min. Surface applications with bitumen emulsions were also highly effective in preventing erosion of large clods but were less effective for small clods. When the bitumen emulsions were mixed with the small clods, the saturated hydraulic conductivity was very high. The infiltration rate was low because water would not enter the clod bed and stable clods were carried in the runoff water.

72-73:04D-003
EFFECT OF LONG-TERM MANAGEMENT ON PHYSICAL AND CHEMICAL PROPERTIES OF THE COSHOCTON WATERSHED SOILS,
Edwards, W. M., McGuiness, J. L., Van Doren, D. M., Jr., Hall, G. F., and Kelley, G. E.
United States Department of Agriculture, Agricultural Research Service, North Appalachian Experimental Watershed, Coshocton, Ohio.
Soil Science Society of America Proceedings, Vol. 37, No. 6, p 927-930, November-December, 1973. 5 tab, 22 ref.

Descriptors: *Water supply development, *Soil conservation, Water conservation, Runoff, Fertility, Erosion control, Water pollution sources.

After 30 years of differential treatment, 0.7- to 3.2-ha watersheds in improved management had higher crop yields and less runoff and erosion than watersheds under prevailing management. Soil samples were taken from the topsoils, plowsoles, and B horizons of the watersheds to determine the effect of such management on soil physical and chemical characteristics. Large changes in chemical characteristics resulted from the higher fertilization associated with improved management but the changes generally did not persist below the topsoil layer. Measurable differences in physical characteristics of the watershed soils were slight and were confined to the topsoil layer. Differences in crop yield and hydrologic performance are attributed to fertilization, crop growth, and tillage differences associated with the two levels of management.

72-73:04D-004
HYDROLOGIC AND WATERSHED MODELING FOR REGULATING WATER QUALITY,
Konrad, J. G., and Cain, J. M.
Natural Resources Department, Water Resources Management Section, Madison, Wisconsin.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 3, p 580-581, May-June, 1973. 4 ref.

Descriptors: *Computer models, *Mathematical models, Watershed management, Water quality, Hydrology.

A state-of-the-art summary is presented. The opinions of the authors as to where modeling is going are also listed.

WATER QUALITY MANAGEMENT AND PROTECTION

IDENTIFICATION OF POLLUTANTS (Group 05A)

72-73:05A-001
USE OF X-RAY FLUORESCENCE TO DETERMINE TRACE METALS IN WATER RESOURCES,
Blasius, M. B., Kerkhoff, S. J., Wright, R. S., and Cothern, C. R.
Dayton University, Ohio, Department of Physics.
Water Resources Bulletin, Vol. 8, No. 4, p 704-714, August 1972. 11 fig, 1 tab, 38 ref.

Descriptors: *Trace elements, *Water analysis, *X-ray fluorescence, X-ray analysis, Fluorescence, Sampling, Water chemistry, Ion exchange, Water quality, Pollutant identification.
Identifiers: Ion exchange filter paper.

The X-ray fluorescence method may be used to analyze trace metals collected in particulate form on filter papers and from the ionic state by ion exchange filter papers. The samples are prepared by allowing water to pass through these filter papers. The procedures necessary for using the X-ray fluorescence method are described. A number of samples were taken from the Great Miami River in Dayton, Ohio over one year, showing the presence of Ca, Ti, Cr, Fe, Cu, Zn, Sr, and Cd. Elements in the periodic table between Ti and Cs were detectable to a sensitivity limit of the order of 30 ppb for metals in the particulate form and 0.4 ppm for metals in the ionic form.

72-73:05A-002
SUITABILITY OF FREEZING AS A METHOD OF PRESERVING RUNOFF SAMPLES FOR ANALYSIS OF SOLUBLE PHOSPHATE,
Nelson, D. W., and Romkens, M. J. M.
Purdue University, Lafayette, Indiana, Department of Agronomy.
Journal of Environmental Quality, Vol. 1, No. 3, p 323-324, July-September, 1972. 2 tab, 8 ref.

Descriptors: *Phosphates, *Storm runoff, *Sampling, *Freezing, Water pollution sources, Water pollution control, Water quality control, Pollutant identification, Sediments.
Identifiers: *Orthophosphates.

Slow freezing of surface runoff samples decreased the levels of soluble orthophosphate in the water phase by 2% to 27%; however, low temperature storage at 2C for 3 days or freezing of the water phase after sediment removal did not change the orthophosphate concentrations. After it was discovered that rapid freezing also resulted in a decrease in orthophosphate concentration, it was concluded that freezing is a poor method to be used in this instance unless the sediment is removed before freezing.

72-73:05A-003
VACUUM EXTRACTORS TO ASSESS DEEP PERCOLATION LOSSES AND CHEMICAL CONSTITUENTS OF SOIL WATER,
Duke, H. R., and Haise, H. R.
United States Department of Agriculture, Fort Collins, Colorado.

Soil Science Society of America Proceedings, Vol. 37, No. 6, p 963-964,
November-December, 1973. 3 fig.
(See 72-73:02G-114)

72-73:05A-004
REMOVAL OF METAL IONS BY SOIL,
Wentink, G. R., and Etzel, J. E.
Greeley and Hansen, Chicago, Illinois.
Journal Water Pollution Control Federation, Vol. 44, No. 8, p 1561-1574, August, 1972. 2 fig, 14 tab, 4 ref.

Descriptors: *Soils, *Heavy metals, Waste water treatment, *Cation exchange, Ions, Industrial wastes, Chromium, Copper, Zinc, Ion exchange, Clays, Sulfates, Sampling, Soil types, Leaching, Leachate, Loam, Flame photometry, Methodology.
Identifiers: *Metal plating wastes, *Pollutant removal, Venoclysis apparatus, Sodium saturation, Atomic absorption spectrophotometry, Ion exchange capacity.

Ion exchange methods in removing metal plating wastes using different types of soil were investigated. Chrome, copper, and zinc in sulfate forms were chosen as the heavy metal ions for study. Solutions of these compounds were added to samples of three soil types: Xenia silt loam, Chalmers silty clay loam, and Elston loam by introducing them at the top of the soil column at a low hydraulic rate using a venoclysis apparatus. Testing to determine cation exchange capacity was accomplished by the sodium saturation method whereby exchange sites in the soil sample are saturated with sodium and the sodium ions are replaced with ammonia ions. The concentration of recovered sodium is measured by flame photometry and the results are expressed in terms of me/100 g of oven-dry soil. The technique was modified for use on soil containing the test ions with metal ion concentrations measured by atomic absorption methods. Metal ion removal in the three sample types was accomplished by an ion exchange mechanism with exchange capacity increasing with clay mineral content. Chrome in concentrations up to 300 mg/l could be removed completely in all three soils, so could copper after an initial conditioning period. Zinc removal was accomplished at efficiency rates of not less than 99.7 percent. It was also found that regeneration of all three soil types was possible.

72-73:05A-005
AUTOMATED FLUOROMETRIC METHOD FOR DETERMINATION OF BORON IN WATERS, DETERGENTS AND SEWAGE EFFLUENTS,
Afghan, B. K., Goulden, P. D., and Ryan, J. F.
Department of Energy, Mines and Resources, Burlington (Ontario). Canada Center for Inland Waters.
Water Research, Vol. 6, No. 12, p 1475-1485, December 1972. 6 fig, 4 tab, 10 ref.

Descriptors: *Boron, *Pollutant identification, *Water analysis, *Chemical analysis, *Sewage effluents, *Methodology, *Detergents, Automation, Chemical reactions, Snow, Ions, Organic compounds.
Identifiers: Chemical interference, 4'-chloro-2-hydroxy-4-methoxybenzophenone, Detection limits, Boric acid, Borax, Sodium perborate, Tetraphenyl boron.

An automated method for the determination of boron in natural waters, detergents and sewage effluents is described. The method is based on the reaction of 4'-chloro-2-hydroxy-4 methoxybenzophenone (CHMB) with boron to produce fluorescent species, in a 90 percent sulfuric acid medium. The method has been made specific to remove any interferences from all major and minor ions and other organic compounds normally present in water. The method is capable of measuring different chemical forms of boron such as boric acid, borax, sodium perborate and tetraphenyl boron. The method analyzes 10 samples per hour, in the 5-100 ppb boron range. The rate of sample analysis can be increased to 20 per hour at higher concentration ranges. The limit of detection is 1 ppb boron.

Section XXIII

WATER QUALITY MANAGEMENT AND PROTECTION

SOURCES OF PULLUTION (Group 05B)

72-73:05B-001
NITRATE IN DEEP SOIL PROFILES IN RELATION TO FERTILIZER RATES AND LEACHING VOLUME,
Pratt, P.F., Jones, W.W., and Hunsaker, V.E.
California University, Riverside.
Journal of Environmental Quality, Vol 1, No 1, p 97-102, January-March 1972.
5 fig, 6 tab, 8 ref.

Descriptors: *Nitrates, *Fertilizers, *Leaching, *Soil water movement, *Path of pollutants, Groundwater movement, Denitrification, Unsaturated flow.

The NO3 concentration in saturation extracts and soil solutions was determined in 30-m profiles in six treatments of a long-term fertility trial with citrus and in four commercial citrus groves in which the depth of sampling was 15 m or to the top of the water table. Drainage volumes and excess N in the soil, calculated as N input minus crop removal, provided a reasonable estimate of the NO3 concentration of water in the unsaturated zone in open-porous soils when inputs were about 150 kg/ha per year. However, at higher rates of inputs to porous soils or at low rates with soils with profiles which had to be assumed to obtain a reasonable N balance. Calculated transit times for water to move 30 m in the unsaturated zone varied from 12 to 49 years.

72-73:05B-002
DENITRIFICATION AND NITRATE REDUCTION IN WISCONSIN LAKE SEDIMENTS,
Chen, R.L., Keeney, D.R., Graetz, D.A., and Holding, A.J.
Wisconsin University, Madison.
Journal of Environmental Quality, Vol 1, No 2, p 158-162, April-June, 1972.
5 fig, 2 tab, 21 ref.

Descriptors: *Nitrification, *Denitrification, *Nitrates, *Nutrient removal, *Water pollution sources, Water quality, Laboratory tests, Sediments, Groundwater, Eutrophication.
Identifiers: *Seepage lakes.

Laboratory and field experiments were conducted to investigate the fate of 15 N labelled NO3-N in Wisconsin lake sediment-water systems. Approximately 90% of the added NO3-N disappeared from a calcareous sediment compared to about 40% from a non-calcareous sediment after 48 hours when incubated under helium; this was a laboratory study result. The recovery of significant amounts of NH4-N particularly in calcareous sediment indicated that immobolized N was subject to rapid mineralization Nitrate-15 N not accounted for was assumed lost through denitrification. In field studies 15NO3-N added to calcareous sediment samples and returned to the lake bottom in wide mouth plastic bottles disappeared within 4 days. About 37% of the added NO3-N was in the organic and NH4-N fractions after 4 days while the remaining 63% was lost through denitrification. These data illustrate that denitrification and nitrate reduction in sediments receiving nitrate from groundwaters must be evaluated in calculating nitrogen budgets of seepage lakes.

72-73:05B-003
EFFECTS OF SEDIMENT ON WATER QUALITY,
Stall, J.B.
Illinois State Water Survey, Urbana.
Journal of Environmental Quality, Vol 1, No 4, p 353-360, October-December 1972. 5 fig, 4 tab, 28 ref.

Descriptors: *Sediment load, *Turbidity, *Sediment yield, *Illinois, *Water pollution effects, Water pollution, Path of pollutants, Soil erosion, Water chemistry, Water quality, Urbanization, Erosion control, Sediment control, Turbidity.

Flowing water in a stream carries sediment which is considered a pollutant because it interferes with many uses of water. Other pollutants in the water may be attached to or greatly affected by the sediment. The ultimate source of most sediment is soil loss from sheet erosion. Soil loss may be as high as 100 metric tons/ha per year on a steep, loose, cropped soil, or on any soil left bare during construction activity. Nearly level land in Illinois may lose 10 tons/ha per year regularly. Rivers carry a load of suspended sediment as a part of their total energy balance. If the suspended sediment load of a river is reduced, the stream will erode its bed or banks to pick up sediment to re-establish its energy balance. Traditional soil conservation measures will reduce soil loss from the farmer's field; this will also reduce sediment yield to a downstream reservoir. Reductions are often 70% to 90%.

72-73:05B-004
DDT AND TOXAPHENE MOVEMENT IN SURFACE WATER FROM COTTON PLOTS,
Bradley, Jr., J.R., Sheets, T.J., and Jackson, M.D.
North Carolina State University, Raleigh.
Journal of Environmental Quality, Vol 1, No 1, p 102-105, January-March 1972.
1 fig, 3 tab, 15 ref.

Descriptors: *Runoff, *Sediment, *Pesticide movement, *Pesticide pollution, *Water pollution sources, Chlorinated hydrocarbon pesticides, Pesticide residues, Path of pollutants, Farm wastes, North Carolina.

When 13.4 kg/ha of DDT were applied to cotton (Gossypium hirsutum L.) during the 1969 growing season, 2.83% was found in natural runoff between July 11, 1969 and January 5, 1970. About 96% of the DDT in runoff was associated with suspended sediment. Of 26.8 kg/ha of toxaphene applied, 0.36% was detected in runoff, and 75% of the toxaphene in runoff was in the sediment fraction. When DDT and toxaphene were applied to the same plot (13.4 and 26.8 kg/ha, respectively, over the season) only 1.03% of the DDT was found in runoff, and the percentage for toxaphene was 0.61. A much greater percentage of DDT and toxaphene remained as soil residues than was found in runoff, but a high percentage of the pesticides applied was not recovered. Residues of DDT in water from a small pond within one experimental watershed ranged from <0.35 ppb before spraying to 65 ppb about midseason.

72-73:05B-005
INFLUENCE OF AGRICULTURAL PRACTICES ON WATER QUALITY IN NEBRASKA: A SURVEY OF STREAMS, GROUNDWATER, AND PRECIPITATION,
Olson, R.A., Seim, E.C., and Muir, J.
Nebraska University, Lincoln.
Water Resources Bulletin, Vol 9, No 2, p 301-311, April 1973. 3 fig, 2 tab, 11 ref.

Descriptors: *Water pollution sources, *Nebraska, *Fertilizers, *Irrigation practices, Farm wastes, Path of pollutants, Water quality, Nitrates, Phosphates, Nutrients, Water pollution effects, Groundwater, Surface waters.

Where nutrient levels of streams in Nebraska are elevated, the cause is usually industrial, sewage or livestock waste intrusion, and not crop production practices. The only significant quantity of nutrient N and P induced by cultivation is that accompanying sediments from eroded fields. The P content of Nebraska groundwater has remained essentially constant during the past 10 years while average NO3 has increased slightly, in a period during which farmer fertilizer use quadrupled. During the same time, irrigation acreage has increased by 50%, livestock numbers by 30%, with corresponding growth in human population and attendant industries. Irrigation practice has contributed more than any other factor to the small increase in groundwater NO3.

72-73:05B-006
GROUNDWATER QUALITY IN THE CORTARO AREA NORTHWEST OF TUCSON, ARIZONA,
Schmidt, K.D.
Water Resources Bulletin, Vol 9, No 3, p 598-606, June 1973. 2 fig, 3 tab, 12 ref.

Descriptors: *Water quality, *Groundwater, *Path of pollutants, *Arizona, *Waste disposal, Sewage disposal, Infiltration, Nitrates, Coliforms, Alluvium, Malenclaves, Hydrogeology, Groundwater movement.
Identifiers: *Tucson (Ariz).

The Cortaro area is used for disposal of much of the liquid waste from the city of Tucson, Arizona. In the past, more than one-half of the sewage effluent was used for crop irrigation. However, since 1970 virtually all of the sewage effluent has been percolated in the normally dry Santa Cruz River channel. Nitrate and chloride contents are monitored in water samples from about 20 large-capacity irrigation wells. Contents and seasonal trends for these constituents are closely related to the disposal of sewage effluent. Water quality problems other than nitrate include total dissolved solids, boron, coliform, and lead. High lead contents in the area appear to be a natural phenomenon and the coliform contents are related to poor well construction. The other quality problems are primarily caused by sewage effluent.

72-73:05B-007
MICROBIOLOGICAL QUALITY OF SUBSURFACE DRAINAGE WATER FROM IRRIGATED AGRICULTURAL LAND,
Smith, J.H., Douglas, C.L., and Bondurant, J.A.
Agricultural Research Service, Kimberly, Idaho, Snake River Conservation Research Center.
Journal of Environmental Quality, Vol 1, No 3, p 308-311, July-September, 1972. 1 fig, 4 tab, 8 ref.

Descriptors: *Irrigation water, Groundwater, *Bacteria, *Coliforms, Water pollution, Groundwater movement, Water pollution sources, Water pollution control, Water quality, *Idaho, Path of pollutants.
Identifiers: Fecal coliforms.

Irrigation and subsurface drainage waters were sampled from a district in southern Idaho and evaluated for bacteriological quality. The sampling took place in the summer of 1969 at two week intervals. From 140 to 3,300 coliforms per 100 ml were contained in the diverted irrigation water. However, 86% of the subsurface drainage samples contained 5 or fewer coliforms per 100 ml. Apparently percolation through the soil improved the water quality almost to domestic water standards.

72-73:05B-008
PESTICIDE-SEDIMENT-WATER INTERACTIONS,
Pionke, H.B. and Chesters, G.
Agricultural Research Service, Chickasha, Oklahoma, Southern Great Plains Watershed Research Center.
Journal of Environmental Quality, Vol 2, No 1, p 29-45, January-March, 1973. 9 fig, 1 tab, 150 ref.

Descriptors: *Pesticides, *Sediments, Aquatic soils, Water pollution sources, Limnology, Aquatic plants, Balance of nature, *Sediment-water interfaces, *Lake sediments, *Reviews.

Pesticide-sediment-water interactions occurring within a watershed and the associated aquatic system are reviewed regarding their impact on the distribution and persistence of pesticides in recipient lakes. Pesticidal persistence on the watershed is discussed initially because the aquatic residue hazard depends largely on the persistence of soil-applied pesticides. Mechanisms of transport from field to aquatic system are reviewed for those compounds not degraded rapidly to nontoxic derivatives. Pesticide transport through the atmosphere, ground water, and surface runoff is traced with particular emphasis on application-associated losses and transport effect on initial pesticide distribution and concentration in the aquatic system. Field and plot studies evaluating pesticide losses in runoff are summarized. Within the aquatic system, limnological, sediment and water characteristics potentially alter the distribution of adsorbed pesticide between water and associated sediment within the lake. Specifically, the effects of pH, lake stratification, characteristics and content of sediment organic matter and clay, and salinity are evaluated. This review concluded with a discussion of literature on pesticide persistence determined in simulated or natural aquatic systems and the interactions between aquatic vegetation, sediment, and water which affect pesticide distribution.

72-73:05B-009
A STATISTICAL METHODOLOGY FOR PREDICTING THE POLLUTANTS IN A RIVER,
Nour, A. Abouel and Razek, A.
Mississippi State University, State College
Water Resources Bulletin, Vol 8, No 1, p 15-23, February 1972. 2 fig, 3 tab, 6 ref.

Descriptors: *Statictical models, *Water pollution, *Path of pollutants, Mathematical models, Regression analysis, Water pollution sources, Water pollution effects.
Identifiers: *Pearl River (Miss).

Accurate, reliable, and sensitive water quality prediction models may be constructed by dividing a natural stream into independent reaches based on physical criteria. Predicting equations of the water pollutants are obtained by regression in a selected stream. Water quality data were gathered in the Pearl River, which flows southwest and then turns south through the states of Mississippi and Louisiana. This evaluation serves as guidelines to divide the total river basin into reaches (subsystems). After subsystem assignment, a stepwise multiple regression FORTRAN program is used to regress the pollutants (dependent variables) for both time and space on their water characteristics (independent variables). The statistical approach provides a practical tool for developing regression equations for water pollution prediction.

72-73:05B-010
LINE SOURCE DISTRIBUTIONS IN TWO DIMENSIONS: APPLICATIONS TO WATER QUALITY,
DiToro, D.M.
Manhatten College, Bronx, N.Y. Environmental Engineering and Science Program.
Water Resources Research, Vol 8, No 6, p 1541-1546, December 1972. 2 fig, 1 tab, 9 ref.

Descriptors: *Dispersion, *Chemical degradation, *Path of pollutants, *Mathematical models, Numerical analysis, Mixing, Biochemical oxygen demand, Dissolved oxygen, Oxygen sag, Mass transfer, Currents (Water), Estuaries.

The steady state two-dimensional concentration distribution that results in the horizontal plane from the continuous discharge of a concenservative substance into an infinite body of water is analyzed. The analysis is readily extended to sequentially reacting substances, so that the solution can be applied to the calculation of concentration distributions of biochemical oxygen demand (BOD) and dissolved oxygen (DO) deficit. The resulting solutions are easily applied by using a table and figures. A numerical example is presented to illustrate the method. The approach is essentially the two-dimensional analog of the steady state analysis conventionally applied to a one-dimensional estuary. The physical situation is given as an infinite vertically well-mixed body of water, which may be tidal, for which the predominant mass transport mechanism is dispersion. A uniform line source of mass decays following first order kinetics in a two-dimensional dispersive field.

72-73:05B-011
ABSORPTION OF WATER BY A SOIL FROM A CIRCULAR CYLINDRICAL SOURCE,
Singh, R.
California State University, San Jose, Dept. of Civil Engineering and Applied Mechanics,
Water Resources Research, Vol 8, No 6, p 1581-1589, December 1972. 4 fig, 11 ref.

Descriptors: *Path of pollutants, *Radioactive wastes, *Diffusion, *Soil water movement, *Translocation, Equations, Radioactive waste disposal, Malenclaves, Ion exchange, Heat flow, Mass transfer, Ion transport, Groundwater movement.

Underground burying of radioactive liquid and solid wastes has been practiced for years at Hanford, Oak Ridge, and other places. These highly dangerous wastes can diffuse out in lateral directions if the containers crack due to earthquakes and internal pressures in relatively thin confined stratum. These situations are often characterized as the absorption of moisture by the partially saturated soil surrounding the disposal site. This phenomenon is governed by a nonlinear partial differential equation, subject to initial and boundary conditions. A method of weighted residuals is applied to extract an explicit solution, which is simple for applications. The solution is valid for any form of the diffusivity function and can be used with any value of initial moisture content.

72-73:05B-012
FINITE ELEMENT METHOD FOR THE HYDRODYNAMIC DISPERSION EQUATION WITH MIXED PARTIAL DERIVATIVES,
Nalluswami, M., Longenbaugh, R.A., and Sunada, D.K.
Colorado State University, Fort Collins, Dept. of Civil Engineering.
Water Resources Research, Vol 8, No 5, p 1247-1250, October 1972. 1 fig, 10 ref.

Descriptors: *Dispersion, *Groundwater movement, *Mathematical models, *Finite element analysis, Numerical analysis, Mathematical studies, Diffusion, Mixing, Path of pollutants, Convection.

A method was developed to extend the use of the finite element technique for solving the two-dimensional dispersion equation. The dispersion coefficients are treated as second order symmetric tensors. The concentration of the dispersing tracer is assumed to be given by a linear polynomial. By means of variational principles a new functional was developed to include the mixed partial derivatives resulting from the anisotropy of the dispersion coefficient. The application of the minimization procedure and the finite element method leads to a set of simultaneous first order linear differential equations.

72-73:05B-013
REGIONAL ANALYSIS OF STREAMFLOW CHEMICAL QUALITY IN TEXAS,
Steele, T.D., and Jennings, M.E.
Geological Survey, Washington, D.C. Water Resources Div.
Water Resources Research, Vol 8, No 2, p 460-477, April 1972. 10 fig, 7 tab, 18 ref.

Descriptors: *Regional analysis, *Water quality, *Texas, *Statistical methods, *Regression analysis, Variability, Correlation analysis, Hydrologic data, Water chemistry, Sampling, Surface waters.

Thirty-one streamflow water quality stations in Texas, with long-term historical records ranging from 7 to 28 years, were selected for statistical analyses of the annual mean concentrations of the major chemical constituents. A statewide multiple regression analysis using frequency characteristics of annual mean water quality constituents as dependent variables and selected basin characteristics as independent variables was investigated as a means of regionalizing information on annual water quality characteristics. For the two different regression models investigated, a single independent variable, generally stream discharge or average basin rainfall, explained a significant part of the variance of the dependent water quality variables. A real analysis of residuals of the statewide regression models indicated two distinct regional patterns. Correlation coefficients for the concentration-rainfall regional models ranged from 0.80 to 0.97 and the standard errors of estimate were between 26 and 99% of the means of the dependent variables. An analysis of various concentraion-conductance relationships for the statewide data also gave favorable results, and provided an alternate method for obtaining estimates of streamflow chemical quality characteristics.

72-73:05B-014
WATER POLLUTION AS AFFECTED BY STREET SALTING,
Hawkins, R.H., and Judd, J.H.
State University of New York, Syracuse. Water Resources Center
Water Resources Bulletin, Vol 8, No 6, p 1246-1252, December 1972. 1 fig, 3 tab, 12 ref.

Descriptors: Water pollution sources, *Deicers, *Salts, *Snow removal, *New York, *Path of pollutants, Urban hydrology, Suburban areas, Roads, Highway icing, Stratification, Density stratification, Salinity, Environmental effects, Water pollution sources.
Identifiers: *Street salting, Road salting, Meadowbrook (NY), Syracuse (NY).

The use of salt to melt ice and snow on streets and roads has become prevalent throughout the Northeast U.S. Several states apply as much 20 tons per lane-mile. Eventually the salt reaches streams and lakes. In Meadowbrook, New York, the chloride content reached a high of 11,000 ppm in December 1969. The runoff from the watershed was emitted in several surges. Chloride concentrations declined with the onset of summer, but still remained high suggesting that some of the salt applied during the past winter appeared in the summer streamflow. Salt runoff entered a small lake, and flowed directly to the lake bottom. The buildup of high density saline water in the lower portion of the lake prevented complete mixing in the spring. Incomplete mixing led to anoxic conditions in the lower lake strata. The population of benthic fauna of the lake was changed by the flow of salt water into the lake. From a total of 10 species of dipteran larva and oligochaetes, only 4 species remained.

72-73:05B-015
WATER QUALITY PREDICTION WITHIN AN INTERBASIN TRANSFER SYSTEM,
White, W.A., Tischler, L.F., and Austin, T.A.
Texas Water Development Board, Austin. Systems Engineering Div.
Water Resources Bulletin, Vol 8, No 3, p 483-494. June 1972. 6 fig, 7 ref.

Descriptors: *Water quality, *Inter-basin transfers, *Mathematical models, *Texas, *Planning, Computer programs, Simulation analysis, Systems analysis, *Model studies.
Identifiers: *Texas water plan.

A methodology for predicting the spatial and temporal levels of conservative water quality constituents within a multibasin water resource system is presented. Dissolved solids, sulfates, and chlorides are the constituents used during this investigation; however, any other conservative ion or mineral can be incorporated into the simulation model. The methodology is tested on the proposed Texas Water System. The water quality model, QNET-I, utilizes monthly canal and river flows and reservoir storage levels calculated by the Texas Water Development Board's systems simulation model. Discharge-concentration relationships are developed for each source of water in the system, including significant waste-water discharges. Reservoirs in the system are assumed to be completely mixed with respect to conservative constituents. A mass balance analysis is performed for each node and each month during the simulation period. The output from the water quality simulation is a table of the concentrations of the conservative water quality constituents at each demand point in the system and in each reservoir and canal for every month the system is in operation. The desired quality of the water at the demand locations is used to determine the economic utility of transporting and mixing water from various sources.

72-73:05B-016
A HYBRID COMPUTER PROGRAM FOR PREDICTING THE CHEMICAL QUALITY OF IRRIGATION RETURN FLOWS,
Thomas, J.L., Riley, J.P., and Israelsen, E.K.
Ohio University, Athens Dept. of Civil Engineering.
Water Resources Bulletin, Vol 8, No 5, p 922-934, October 1972. 10 fig, 10 ref.

Descriptors: *Simulation analysis, *Hybrid computers, *Computer programs, *Return flow, *Path of pollutants, Water quality, Water pollution, Water Management (Applied), Mathematical models, Ion exchange, Leaching, Percolation, Calcium, Magnesium, Sodium, Sulfates, Chlorides, Bicarbonates, Irrigation water.

A hybrid computer program was developed to predict the water and salt outflow from a river basin in which irrigation is the major user of water. The model combines a chemical model which predicts the quality of water percolated through a soil profile with a general hydrologic model. The chemical model considers the reactions that occur in the soil, including the exchange of calcium, magnesium, and sodium cations on the soil complex, and the dissolution and precipitation of gypsum and lime. The chemical composition of the outflow is a function of these chemical processes within the soil, plus the blending of undiverted inflows, evaporation, transpiration, and the mixing of subsurface return flows with groundwater. The six common ions of western waters, namely calcium, magnesium, sodium, sulfate, chloride, and bicarbonates were considered in the study. total dissolved solids outflow was obtained by addint the individual ions. The overall model operates on a monthly time unit. The model was tested on a portion of the Little Bear River basin in northern Utah. The model successfully simulated measured outflows of water and each of the six ions for a 24-month period. Preliminary results indicated that the available water supply could be used to irrigate additional land without unduly increasing the salt outflow from the basin. With minor adjustments the model can be applied to other hydrologic areas.

72-73:05B-017
A WATER QUALITY MODEL FOR A CONJUNCTIVE SURFACE-GROUNDWATER SYSTEM: AN OVERVIEW,
Perez, A.I., Huber, W.C., Heaney, J.P., and Pyatt, E.E.
Florida University, Gainesville. Dept. of Environmental Engineering.
Water Resources Bulletin, Vol 8, No 5, p 900-908, October 1972. 8 fig, 25 ref.

Descriptors: *Mathematical models, *Conjunctive use, *Lakes, Water pollution sources, *Florida, Surface-groundwater relationships, Rainfall-runoff relationships, Percolation, Runoff, Leaching, Base flow, Infiltration, Water management (Applied), Water quality, Path of pollutants, Overland flow, Soil water movement, Groundwater movement.
Identifiers: Lake Apopka (Fla).

A mathematical model is designed to predict water quality in a surface-groundwater system. The goal is to obtain cause and effect relationships between pollutant sources and the ensuing concentrations at different locations in a basin. Several programs are used to model rainfall, runoff, flow in surface bodies of water, infiltration, and groundwater flow. At every time step in the simulation, the water quantity computation are performed first. Subsequently, the results of these computation, typically in the form of flow velocities, are used as input to the water quality calculations. The water quality routines involve the modeling of the associated physical, chemical, and biological processes. Empahsis is placed on pollution in agricultural areas. Accordingly the Lake Apopka basin in Central Florida is being used as the application site.

72-73:05B-018
NITRATE CONCENTRAIONS IN GOUNDWATER BENEATH A BEEF CATTLE FEEDLOT,
Lorimor, J.C., Mielke, L.N., Elliott, L.F., Ellis, J.R.
Agricultural Research Service, Gunnison, Colo. Soil and Water Conservation Research Div.
Water Resources Bulletin, Vol 8, No 5, p 999-1005, October, 1972. 4 fig, 3 tab, 6 ref.

Descriptors: Groundwater, Groundwater movement, Aquifer characteristics, Nitrogen, *Nitrates, Piezometers, *Water sampling, Irrigation, Cattle, *Feed lots, Dyes, Tracers, Transmissivity, Hydraulic gradient.
Identifiers: Nitrate-Nitrogen.

In June 1970, a groundwater sampling study was conducted in conjunction with initiation of irrigation pumping from groundwater near a feed lot located in east-central Nebraska. Aquifer characteristics and nitrate-nitrogen concentrations in the water were determined. A dye injected into the water showed that water from beneath the feedlot was being sampled at the wells immediately outside the lot. Groundwater nitrate levels were generally lower down-gradient from the feedlot than they were up-gradient. Nitrate levels in the well samples were not changed significantly by the start of irrigation pumping, although they did appear to increase slightly. Piezometer samples did show a significant difference. Except for two samples obtained during the pumping trial, nitrate-nitrogen was well below the Public Health Service limit of 10 parts per million.

72-73:05B-019
ANNUAL CYCLE IN RIVER WATER QUALITY: A TIMES SERIES APPROACH,
Edwards, A.M.C., and Thornes, J.B.
King's Coll., London (England). Rogate Field Center
Water Resources Research, Vol 9, No 5, p 1286-1295, October 1973. 6 fig, 5 tab, 17 ref.

Descriptors: *Time series analysis, *Water quality, *Streamflow, *Path of pollutants, Frequency analysis, Statistics, Statistical methods, Variability, Regression analysis, Fourier analysis, Correlation analysis.
Identifiers: *River Stour (England).

Regression, spectral, and cross-spectral techniques were used to examine the trends and periodicity in a 20-year record of weekly observations of eight water quality variables in the River Stour, eastern England. Linear regression shows that all except pH and carbonate hardness have significantly increased over time. A strong annual cycle is present. Cross-spectral analysis was used to model the relationship between the variables and the water discharge in time. Nitrate and non-carbonate hardness are positively correlated with discharge, whereas carbonate hardness is an inverse function.

72-73:05B-020
EFFECT OF AGRICULTURAL MANAGEMENT OF WET SLOPING SOIL ON NITRATE AND PHOSPHORUS IN SURFACE AND SUBSURFACE WATERS,
Benoit, G.R.
Agricultural Research Service, Burlington, Vt., New England Watershed Research Center.
Water Resources Research, Vol 9, No 5, p 1296-1303, October 1973. 3 fig, 3 tab, 13 ref.

Descriptors: *Nitrates, *Phosphates, *Path of pollutants, *Water pollution sources, *Fertilizers, Farm wastes, Runoff, Groundwater, Leaching, Infiltration, Drainage water, Subsurface drainage, Drainage practices.

Differences in nitrate and phosphate content of water from three cropping systems were evaluated in a 12-plot study in East Franklin, Vermont, on a poorly drained, sloping Cabot silt loam: (1) timothy, red clover, Kentucky bluegrass hay pasture; (2) corn silage. Six plots were in alfalfa hay, six plots were planted in corn, and the upslope area was in hay-pasture. Soil samples were collected in the summers of 1969 and 1970 and analyzed for total soil nitrogen. Surface and subsurface drain effluent samples from the plots and upslope area were analyzed for nitrates and phosphates. Draining wet sloping land may decrease total soil nitrogen; nitrate nitrogen may be lost from organic matter breakdown in cold but unfrozen soil; nitrates but not phosphates will move both vertically and laterally through the soil to subsurface drains; surface runoff contains few nitrates but significant concentrations of phosphates; and more nitrates were lost from fertilized corn plots than from alfalfa plots or hay pasture areas.

72-73:05B-021
DISPERSION TRANSPORT OF REACTING SOLUTES IN SATURATED POROUS MEDIA: GALERKIN METHOD APPLIED TO EQUILIBRIUM-CONTROLLED EXCHANGE IN UNIDIRECTIONAL STEADY WATER FLOW,
Rubin, J., and James, R.V.
Geological Survey, Menlo Park, California.
Water Resources Research, Vol 9, No 5, p 1332-1356, October 1973. 7 fig, 22 ref.

Descriptors: *Dispersion, *Ion exchange, *Ion transport, *Groundwater movement, Path of pollutants, Water chemistry, Mass transfer, Solutes, Chemical reactions, Saturated flow, Translocation, Leaching, Mathematical studies, Numerical analysis.
Identifiers: *Galerkin method.

Equations describing dispersion and ion exchange in one-dimensional transport of solutes in saturated porous media may be solved numerically by means of the Galerkin method. It is assumed that water flow is steady and that local chemical equilibrium exits throughout the systems considered. No constancy restrictions are placed on the total concentration of the dissolved ions participating in exchange. The cases treated involve (1) homogenous or layered systems, (2) exchange reactions with constant or concentrations dependent selectivity coefficients, (3) binary or multicomponent exchange, and (4) systems in which one of the exchanging ions is also involved in a precipitation-dissolution reaction. The appraoch may be useful in analyzing a variety of solute transport processes of hydrologic interest.

72-73:05B-022
DISPERSION DURING FLOW IN POROUS MEDIA WITH BILINEAR ADSORPTION
Gupta, S.P., and Greenkorn, R.A.
Purdue University, Lafayette, Ind. School of Chemical Engineering.
Water Resources Research, Vol 9, No 5, p 1357-1368, October 1973. 4 fig, 1 tab, 27 ref.

Descriptors: *Path of pollutants, *Dispersion, *Groundwater movement, Numerical analysis, *Adsorption, Porous media, Farm wastes, Industrial wastes, Fertilizers, Pesticides, Herbicides, Water pollution sources.

Major sources of pollution in underground water come from the runoff of cattle feedlots, from runoff of fertilizers, pesticides and herbicides from cultivated lands, and from domestic and industrial wastes. The equations for the dispersion and adsorption of various chemicals in porous media are formulated to calculate pollution movement. If a bilinear rate of adsorption is assumed, two coupled nonlinear parabolic partial differential equations result. The equations can be solved by the Crank-Nicolson method, which is a stable, two-step method. Solutions for the range of variables involved in the movement of pollutants in porous media are obtained for a one-dimensional model.

72-73:05B-023
SURFACE WATER QUALITY IS INFLUENCED BY AGRICULTURAL PRACTICES,
Holt, R.F.
Agricultural Research Service, Morris, Minn. Central Soil Conservation Research center.
Paper No 71-740, presented at the 1971 Winter Meeting, American Society of Agricultural Engineers, Chicago, Illinois, December 7-10, 1971. 19 p, 3 tab, 34 ref.

Descriptors: *Water quality, *Pollutants, *Water pollution, *Water pollution sources, Farm wastes, Watershed management, Land management, Watersheds, Soil amendments, Fertilization.

Fertilization, animal waste handling, soil amendments and cropping practices can all influence the quality of water that runs off an agricultural watershed. Maintenance of high quality surface water demands the development of practices which can minimize the nutrient, pesticide, manure, and sediment loading of water impoundments. The physical trapping or tying down of solid particles can control sediment delivery but not dissolved substances. Utilization of the sorptive capacity of the soil offers a mechanism for controlling the movement of soluble contaminants into water supplies.

72-73:05B-024
ADSORPTION AND TRANSPORT OF AGRICULTURAL CHEMICALS IN WATERSHEDS,
Frere, M.H.
Agricultural Research Service, Durant, Oklahoma. Water Quality Management Lab.
Paper No. 12 presented at the 1971 Winter Meeting, American Society of Agricultural Engineers, Chicago, Illinois, December 7-10, 1971. 12 p, 1 fig, 12 ref.

Descriptors: *Path of pollutants, *Agricultural chemicals, Leaching, Adsorption, Watersheds, Soil-water-plant relationships, Pollutants.

A descriptive model of the pathways of chemicals in the soil-water-plant system is used to catalogue the properties of agricultural chemicals that are important to their movement in watersheds. The chemical interactions dictate the pathways to be followed while the behavior of water controls the time and amount of movement.

72-73:05B-025
PERTURBATION ANALYSIS OF THE EQUATION FOR THE TRANSPORT OF DISSOLVED SOLIDS THROUGH POROUS MEDIA: I. LINEAR PROBLEMS,
Wooding, R.A.
Wisconsin University, Madison. Dept. of Soil Science.
Journal of Hydrology, Vol 16, No 1, p 1-15, May 1972. 4 fig, 26 ref.

Descriptors: *Groundwater movement, *Path of pollutants, *Numerical analysis, *Ion transport, Porous media, Mixing, Diffusion, Leaching, Translocation, Ion exchange, Water chemistry, Saline water-freshwater interfaces.

The technique of matched asymptetic expansions is applied to solute transport in steady one-dimensional flow systems in porous slabs, membranes or columns, assuming linear exchange equilibrium and constant diffusivity. These special cases are studied as a preliminary to the examination of more difficult nonlinear systems. The governing dimensionless parameter is the macroscopic Peclet number. Three cases are treated to illustrate features of the perturbation technique. With a fluctuating diffusion ('back-mixing') layer at the outlet when the input concentration is a fairly slowly varying, arbitrary function of time, the outer problem is hyperbolic and is easily solved, while the inner problem reduces to the solution of a set of ordinary differential equations. With a thickening diffusion layer at a discontinuity between two fairly slowly-varying concentration functions, the solution obtained is qualitatively different from that of the nonlinear case. With the arrival of a diffusion zone (initially a concentration step) at the outlet, the solution possesses features of a fluctuating and thickening diffusion layer. This is a special example with analogies to a 'boundary layer within a boundary layer', and illustrates, in particular, a type of concentration distribution which can be encountered in classic breakthrough experiments.

72-73:05B-026
THE DETERMINATION OF DISPERSION COEFFICIENTS IN NON-HOMOGENEOUS MEDIA IN PROBLEMS OF SALT WATER CONTAMINATION OF FRESH GROUND WATER,
Bonnier, A. and Korganoff, A.
Societe Centrale pour l'Equipment du Territoire-International, Puteaux (France).
Journal of Hydrology, Vol 16, No 1, p 39-47, May 1972. 20 ref.

Descriptors: *Saline water intrusion, *Diffusion, *Mixing, *Path of pollutants, *Mathematical studies, Diffusivity, Dispersion, Equations, Groundwater movement, Mathematical models.
Identifiers: *Coastal aquifers.

Salt-water contamination of fresh groundwater is one of the major problems facing the population of coastal areas. The use of a mathematical model taking into consideration diffusion phenomena requires a knowledge of dispersion parameters which vary from one point to another in a nonhomogeneous medium. A mathematical method for overcoming these difficulties is given.

72-73:05B-027
MINERAL POLLUTION IN THE COLORADO RIVER BASIN,
Blackman, Jr., W.C., Rouse, J.V., Schillinger, G.R., and Shafer, Jr., W.H.
Environmental Protection Agency, Phoenix, Arizona, Colorado River Basin
Water Quality Control Project.
Journal Water Pollution Control Federation, Vol 45, No 7, p 1517-1557,
July 1973. 24 fig, 14 tab, 19 ref.

Descriptors: *Salinity, *Water pollution sources, *Colorado River, Irrigation water, Leaching, Salts, Runoff, Chlorides, Bicarbonates.

Concentrations of total dissolved solids (salinity) in Colorado River basin streams are a major problem for lower basin water users. Salinity concentrations in unregulated streams of the basin comprise two distinct populations that are grouped into base flow months and runoff months. Statistically significant increases in salinity have occurred with increasing water use, and in downstream progression. Upper basin salt load contributions are: runoff, 52 percent; irrigated agriculture, 37 percent; natural point sources and flowing wells, 9 percent; and municipal and industrial, 7 percent. Lower basin contributors are: upper basin inflow, 72 percent; natural point sources, 15 percent; irrigated agriculture, 9 percent; runoff, 4 percent, and municipal and industrial, less than 1 percent. Salt yields from irrigated lands range from near 0 to 8.5 tons/yr/acre. Greatest yields are from irrigation of and runoff from lands underlain by Mancos shale and Tertiary lake beds. Headwater areas yield predominantly calcium bicarbonate waters. Saline sediments in lower valleys cause waters to become predominantly high in sodium calcium sulfate ions.

72-73:05B-028
FACTORS AFFECTING THE PERCOLATION TEST,
Healy, K.A. and Laak, R.
Connecticut Univ., Storrs. Dept of Civil Engineering.
Journal Water Pollution Control Federation, Vol 45, No 7, p 1508-1516,
July 1973. 10 fig, 2 tab, 5 ref.

Descriptors: *Infiltration, *Percolation, *Septic tanks, Soil disposal fields.
Identifiers: *Percolation tests.

A mathematical analysis of the percolation test is presented with both capillary and gravity flow potentials considered. A relation between percolation rate, capillarity, hole shape, and permeability is developed. Laboratory percolation tests qualitatively support the analysis. Field percolation tests show no correlation between percolation rate, permeability, or position of the water table. The percolation test seems to be an unreliable method of determining the water absorption capability of a soil deposit.

72-73:05B-029
NITROGEN AND PHOSPHORUS CONTENT OF WATER FROM TILE DRAINS AT TWO LEVELS OF MANAGEMENT AND FERTILIZATION,
Zwerman, P.J., Greweling, T., Klausner, S.D., and Lathwell, D.J.
Cornell Univ., Ithaca, N.Y., Dept. of Agronomy.
Soil Science Society of America Proceedings, Vol 36, p 134-137, 1972. 1 fig,
7 tab, 10 ref.

Descriptors: *Drainage water, *Fertilization, Water pollution sources, *Leaching, *Nitrogen, *Phosphorus, Tile drains, Agriculture, Nitrates, Ammonia, Phosphates, Agricultural runoff, Soils.
Identifiers: Lima-Kendaia soil.

Since excessive nitrogen and phosphorus are a major cause of increased growth of undesirable aquatic vegetation in lakes and streams and excessive nitrates are a public and animal health hazard, a study was made to compare nitrogen and phosphorus losses from the soil through drainage water under two levels of conservation management. The experimental field was made up of approximately 12 hectares of a Lima-Kendaia soil association. High and moderate rates of fertilization were applied. Effluent from the drains was measured and analyzed for inorganic nitrogen and orthophosphate. During two 3-week test periods, nitrate calculated as nitrogen delivered from the tile drains in kilos/ha per week ranged from .225 to 2.75. Ammonium concentrations seemed to be only slightly related to fertilization, ranging consistently between .02 to .03 ppm. Weekly outputs of ammonia nitrogen calculated as nitrogen were less than .00258 kilos/ha. Orthophosphate concentrations calculated as phosphorus ranged from .004 to .01 ppm with a weekly output range of .00016 to .00088 kilos/ha. Nitrogen was applied as ammonium nitrate. Phosphorus was applied at 46% superphosphate.

72-73:05B-030
PHOSPHORUS LOSSES FROM FOUR AGRICULTURAL WATERSHEDS ON MISSOURI VALLEY LOESS,
Schuman, G.E., Spomer, R.G., and Piest, R.F.
Agricultural Research Service, Lincoln, Nebraska, North Central Region.
Soil Science Society of America Proceedings, Vol 37, No 3, p 424-427,
May-June 1973. 6 tab, 15 ref.

Descriptors: *Phosphates, *Soil erosion, *Water pollution sources, *Path of pollutants, Adsorption, Sediment yield, Sheet erosion, Suspended load, Erosion control, Loess, *Iowa.

Phosphorus losses from four field-size experimental watersheds at Treynor, Iowa, were measured during 1969-71. A contour-planted corn watershed and a pasture watershed were fertilized at the recommended P rate (39 kg/ha). A level-terraced and a second contour-planted corn watershed were fertilized at 2.5 times this rate. At the high level of P fertilization, phosphorus loss by surface runoff from the contour-planted corn watershed was 0.495 kg/ha in 1969, 1.034 kg/ha in 1970, and 2.130 kg/ha in 1971. Level terraces greatly reduced P loss by reducing runoff and erosion. Water samples for all runoff events taken above the overfall of each watershed gully contained considerably more inorganic P in solution than samples taken at the weir site, 70 to 230 m downstream. This reduction in solution P was caused by the adsorption of P by the additional suspended soil material entering the stream from gully erosion.

72-73:05B-031
SOIL STORAGE LIMITATIONS ON EFFLUENT IRRIGATION,
Settergren, C.D.
Missouri University, Columbia.
Water Resources Bulletin, Vol 8, No 6, p 1273-1276, December 1972
2 fig, 9 ref.
(See 72-73:05E-001)

72-73:05B-032
ON THE NECESSARY AND SUFFICIENT CONDITIONS FOR A LONG-TERM IRRIGATED AGRICULTURE,
Moore, C.V.
United States Department of Agriculture, Economic Research Service,
Davis, California.
Water Resources Bulletin, Vol 8, No 4, p 802-812, August 1972. 3 fig, 12 ref.

Descriptors: *Water quality, *Irrigation effects, *Salinity, Salt balance, Irrigation practices, Water management (applied), Drainage, Water pollution sources, Soil analysis, Soil chemical properties, Irrigated land, Irrigation water.

Salinization and water logging have been the nemesis of irrigated agriculture societies. Low quality water substitutes for high quality water for irrigation at an increasing rate up to the limits of the soil's ability to transmit the additional water and remove excess salts from the root zone. Soil transmissibility can be increased by additional investment in drainage ditches and underground tile. Low valued-high salt tolerant crops can be substituted for higher valued-salt sensitive crops to maintain production in areas served by irrigation water sources of deteriorating quality. Thus physical factors specify the necessary conditions for survival of an irrigated agriculture. The conditions for survival must be in terms of a positive net income in each subplanning period discounted to its present value.

72-73:05B-033
ESTIMATION PROCEDURES FOR RESPONSE FUNCTIONS OF CROPS TO SOIL WATER CONTENT AND SALINITY,
Yaron, D., Bielorai, H., Shalhevet, J., and Gavish, Y.
Hebrew University, Jerusalem, Israel.
Water Resources Research, Vol 8, No 2, p 291-300, April 1972. 6 tab, 4 fig, 21 ref.
(See 72-73:02G-041)

72-73:05B-034
MOVEMENT OF NITRATES UNDER IRRIGATED AGRICULTURE,
Edwards, D.M., Fischbach, P.E., and Young, L.L.
Nebraska University, College of Engineering and Architecture, Lincoln.
Transactions of the American Society of Agricultural Engineers, Vol 15, No 1, p 73-75, January-February, 1972. 6 fig, 14 ref.

Descriptors: *Nitrates, *Nitrogen, *Water pollution sources, Leaching, Water quality, Nutrient removal, Fertilizers, Nitrogen compounds.

Nitrate nitrogen is highly soluble in water, thereby posing a threat of water pollution. A coordinated sequence of laboratory and field studies were conducted. Both mechanical placement and hydraulic injection were to apply the fertilizer. The following conclusions were drawn: 1. once nitrates move below the soil surface they do not re-enter the runoff water; 2. nitrates move with the wetting front; 3. with a properly managed irrigation system little or no movement of nitrates outside the root zone should occur.

72-73:05B-035
LOSSES OF ATRAZINE IN RUNOFF WATER AND SOIL SEDIMENT,
Hall, J.K., Pawlus, M., and Higgins, E.R.
Pennsylvania State University, University Park Dept. of Soil Chemistry.
Environmental Quality Vol 1, No 2, p 172-176. 1972 Illustration.

Identifiers: *Atrazine loss, Herbicides, Oats, Runoff, Sediment, Soil sediment, Toxicity, Zeamays, *Pennsylvania, *Corn.

Atrazine losses in runoff water and soil sediment were determined in 1967 and 1968 after 7 rates (0, 0.6, 1.1, 2.2, 4.5, 6.7, and 9.0 kg/ha) of atrazine were applied pre-emergent to corn (Zeamays L.) seeded on field plots of Hagerstown silty clay loam (14% slope). Average losses for all rates in 1967 in runoff water and soil sediment equaled 2.4% and 0.16% of the total applied, respectively. In 1967, at the recommended rate (2.2 kg/ha) for preemergence applications to Pennsylvania soils, composite losses were 2.5% of the applied or approximately 0.05% kg/ha. In 1968, 1 yr after atrazine application, the average loss over all rates for the combines substrates was 0.01%. Analyses of soil core samples taken from all plots in 1967 revealed that 1 mo. after atrazine application an average of 67.9% remained in the soil, and 3 mo. later recoveries had decreased to 21.4% of that applied. The following year atrazine remaining in the soil had decreased to 15.9% in April and to 5.4% in September. At the recommended rate of application, recoveries decreased from 39% of that applied to 9% for the same time period in 1967. In 1969, typical atrazine toxicity symptoms were found in oats growing on plots which had received 6.7 and 9.0 kg/ha of atrazine in 1967. Damage was confined to the uppermost parts of the slope.

72-73:05B-036
NITRATE IN SURFACE AND SUBSURFACE FLOW FROM A SMALL AGRICULTURAL WATERSHED,
Jackson, W.A., Asmussen, L.E., Houser, E.W., and White, A.W.
Agricultural Research Service, Watkinsville, Georgia.
Journal of Environmental Quality, Vol 2, No 4, p 480-482, October-December 1972. 1 fig, 2 tab, 8 ref.

Descriptors: *Nitrates, *Path of pollutants, *Fertilizers, *Georgia, Corn (field), Water quality, Nutrients, Subsurface drainage, *Agricultural watersheds.

A small agricultural watershed on Cowarts loamy sand in the Georgia Coastal Plains was planted in corn each year from 1969 to 1971. Surface and subsurface water samples were collected during each natural rainfall runoff event and No3-N was determined. The initial weighted average No3-N concentration was 5 ppm in the subsurface runoff for 3 months before the first planting. The average was 7 ppm in 1969, 10 ppm in 1970, and 9 ppm in 1971. The concentration of NO3-N in most of the surface runoff for 3 years was less than 1 ppm; the maximum was 3 ppm. Subsurface flow accounted for 80% of the total runoff during the study period. Thus, greater amounts of NO3-N were discharged in subsurface flow than in surface flow from this watershed.

72-73:05B-037
ISOTOPHIC TRACER TECHNIQUES FOR IDENTIFICATION OF SOURCES OF NITRATE POLLUTION,
Edwards, A.P.
Tennessee Valley Authority, Muscle Shoals, Alabama, Division of Agricultural Development.
Journal of Environmental Quality, Vol 2, No 3, p 382-387, July-September 1973. 4 tab, 25 ref.

Descriptors: *Tracers, *Path of pollutants, *Nitrates, Nitrogen, Radioisotopes, Fertilizers, Pollutant identification.

The use of labeled fertilizers with N-15 contents substantially higher or lower than the natural abundance figure is the only valid approach to the measurement of fertilizer contribution to the NO3 appearing in tile drains under field condition. The natural N-15 abundance approach to the measurement of percentage contribution of applied fertilizers to nitrate production was not successful in well-replicated laboratory incubation experiments. Time of incubation may be eliminated as a variable by incubating the control and fertilized sample for the same time and under exactly the same conditions.

72-73:05B-038
SALT PICKUP FROM AGRICULTURAL LANDS IN THE GRAND VALLEY OF COLORADO,
Skogerboe, G.V., and Walker, W.R.
Colorado State University, Fort Collins, Department of Agricultural Engineering.
Journal of Environmental Quality, Vol 2, No 3, p 377-382, July-September 1973. 7 fig, 3 tab, 7 ref.

Descriptors: *Water pollution sources, *Colorado River, *Salinity, *Path of pollutants, Return flow, Irrigation, *Colorado, Water pollution, Water quality, Salts.
Identifiers: *Grand Valley (Colo).

Introduction of seepage and deep percolation losses to saline soils and aquifers, and the eventual return of these flows to the river system with their large salt loads, make the Grand Valley in Colorado one of the more significant salinity sources in the Upper Colorado River basin. The principal components of both the water and salt flow systems were delineated, and water and salt budgets were generated on a monthly basis for the water years 1969-1971. About 51,039 metric tons of dissolved solids are being added from the small 1876 ha test area. This salt contribution of about 27.1 metric tons/ha is proportionate to the valley-wide pickup. From this analysis, it is concluded that salinity control alternatives must focus on reducing the flow of water in the groundwater system. Possible measures include conveyance channel linings and improved on-farm water management practices.

72-73:05B-039
NITROGEN TRANSFORMATIONS DURING SUBSURFACE DISPOSAL OF SEPTIC TANK EFFLUENT IN SANDS: II. GROUND WATER QUALITY,
Walker, W.G., Bouma, J., Keeney, D.R., Olcott, P.G.
Wisconsin University, Madison. Department of Soil Science.
Journal of Environmental Quality, Vol 2, No 4, p 521-525, October-December 1973. 4 fig, 1 tab, 12 ref.

Descriptors: *Path of pollutants, *Soil disposal fields, *Nitrogen, *Biodegradation, *Ground water, Soil water, Water pollution sources, Nitrates.

Groundwater observation wells were installed in the immediate vicinity of four septic tank effluent soil disposal systems. Potentiometric maps were constructed from measurements of the groundwater level at each site to establish the direction of movement. Groundwater samples were pumped from each well to establish patterns of N enrichment in the groundwater around the seepage beds and to evaluate the performance of these disposal systems in sands in terms of N removal. Soil disposal systems in sands added significant quantities of nitrate formed by nitrification of NH4, the dominant form of N in the effluent, to underlying groundwater. In sands, the only active mechanism of lowering the NO3-N content is by dilution with uncontaminated groundwater. Relatively large areas of 0.2 ha downgradient were needed before concentrations in the top layer of the groundwater were lower than 10 mg/liter. The average N-input per person was 8 kg per year. Essentially complete nitrification in the soil results in addition of approximately 33 kg NO3-N to the groundwater per year for an average family of four.

72-73:05B-040
NITROGEN TRANSFORMATIONS DURING SUBSURFACE DISPOSAL OF SEPTIC TANK EFFLUENTS IN SANDS: 1. SOIL TRANSFORMATIONS,
Walker, W.G., Bouma, J., Keeney, D.R., and Magdoff, F.R.
Wisconsin University, Madison. Department of Soil Science.
Journal of Environmental Quality, Vol 2, No 4, p 475-480, October-December 1973. 7 fig, 4 tab, 21 ref.

Descriptors: *Soil disposal fields, *Nitrogen, *Path of pollutants, *Biodegradation, Nitrification, Septic tanks, Hydraulic conductivity, Unsaturated flow.
Identifiers: Soil crusting.

Soil physical and chemical studies of five subsurface septic tank seepage beds were conducted to determine the biochemical transformations of N and thereby its potential for groundwater pollution. Effluent was ponded in all the seepage beds examined due to the presence of an impeding layer, a 'crust', at the boundary between the gravel bed and adjacent soil. The crust reduced infiltration rates approximately from 500 to 8 cm/day. Soil atmospheric composition 5 cm below the crust averaged 19.6% O2 and 0.66% CO2. Nitrogen in the septic tank effluent occurred as NH4-N (80%) and organic N (20%) with virtually no NO3-N. Organic-N was largely concentrated in the crust zone. Nitrification of NH4-N to NO3-N was essentially complete and commenced in the unsaturated subcrust soil within about 2 cm of the crust. Nitrification did not occur and NH4-N was absorbed by the soil below a seepage bed that was submerged in the groundwater.

72-73:05B-041

RECYCLING AND RECOVERY OF NITROGEN, PHOSPHORUS, AND POTASSIUM BY COASTAL BERMUDAGRASS: II. UNDER GRAZING CONDITIONS WITH TWO STOCKING RATES,

Rouquette, F.M., Jr., Matocha, J.E., Duble, R.L.
Texas A&M University, Agricultural Research and Extension Center, Overton.
Journal of Environmental Quality, Vol 2, No 1, p 129-132, January-March, 1973.
3 fig, 1 tab, 27 ref.

Descriptors: *Water pollution sources, *Fertilizers, Nitrogen, Phosphorus, Potassium, Nutrient removal, Leaching, Coastal bermudagrass, Pastures, Forages, Groundwater.

The effect of two stocking rates on the recycling of N, P, and K was studied for 2 years on a Coastal bermudagrass. Samples for chemical analysis were taken at 14-day intervals. Available forage, forage yield, and forage consumption were estimated from samples taken at 2- to 4-week intervals. Soil samples were taken prior to, during, and at termination of the grazing trial. Plant nutrient recycling on the high stocked pastures was approximately twice as great during the dry, 1969 season and about 10% higher during the 1970 season compared to that on the low stocked pastures. Recoveries of applied plant nutrients averaged over stocking rates were 84, 50, and 155% for N, P, and K respectively, during 1969, and 180, 73, and 172% for N, P, and K, respectively, during 1970. There was a substantial soil accumulation of plant nutrients under both stocking rates with a considerable advantage in favor of the high stocked pastures.

72-73:05B-042

RECYCLING AND RECOVERY OF NITROGEN, PHOSPHORUS, AND POTASSIUM BY COASTAL BERMUDAGRASS: 1. EFFECT OF SOURCES AND RATES OF NITROGEN UNDER A CLIPPING SYSTEM,

Matocha, J.E., Rouquette, F.M., Jr., and Duble, R.L.
Texas A&M University, Agricultural Research and Extension Center, Overton.
Journal of Environmental Quality, Vol 2, No 1, p 125-129, January-March, 1973. 5 fig, 2 tab, 17 ref.

Descriptors: *Water pollution sources, *Fertilizers, *Nitrogen, Nitrates, Leaching, Nutrient removal, Coastal bermudagrass, Forages, Phosphorus, Potassium, Groundwater.

A field experiment was conducted to determine recovery efficiencies for applied N, P, and K under a system of total removal of forage over a 3-year period. Ammonium nitrate (NH2)2CO, and (NH4)2SO4 were each applied in split application of 0, 280, 560, and 840 kg N/ha each season. Soil levels of total N, chemically extractable P, and K were monitored each season. Characteristic decreases in recoveries occurred with increasing N rates. Average P recovery percentages for NH4NO3 were 34, 46, and 52% for rates of 280, 560, and 840 kg N/ha, respectively. Plant recovery of applied K was greatest for (NH4)2SO4 and lowest for (NH2)2CO. Average values for (NH4)2SO4 were 108, 165, and 222% for the low, medium, and high rates of N, respectively. Ammonium sulfate gave greater accumulation of soil N with time than NH4NO3 or (NH2)2CO while chemically extractable soil P and K were highest for NH4NO3.

72-73:05B-043

CHEMICAL DISTRIBUTION OF RESIDUAL FERTILIZER NITROGEN IN SOIL AS REVEALED BY NITROGEN-15 STUDIES,

Allen, A.L., Stevenson, F.J., and Kurtz, L.T.
Langston University, Department of Agriculture, Langston, Oklahoma.
Journal of Environmental Quality, Vol 2, No 1, p 120-124, January-March, 1973. 5 fig, 18 ref.

Descriptors: *Water pollution sources, *Nitrogen, *Fertilizers, Leaching, Nutrient removal, Nitrates, Radioisotopes, Salinity, Groundwater.

Chemical distribution patterns were obtained for the residual N in field plots previously amended with N15-labeled urea and oxamide. From 25 to 40% of the fertilizer N was present in the soil (0 to 25 cm) after the first growing season, about half of which still remained after 5 years. Essentially all of the fertilizer-derived N occurred in organic combination; only a small fraction was accounted for in inorganic forms, chiefly as fixed NH4. In comparison to the native humus N, higher percentages of the fertilizer N left after the first growing season occurred as amino acids and amino sugars; lower percentages occurred in acid-insoluble N. Considerable humification occurred during the subsequent 4 years with relocation of amino acids N to more resistant humus forms. The findings suggest that fertilizer N, once incorporated into soil organic matter, becomes increasingly stable with time and is not readily mineralized or subject to leaching.

72-73:05B-044
MOVEMENT OF NITRATE NITROGEN IN SOME GRASSLAND SOILS OF SOUTHERN ALBERTA,
Sommerfeldt, T.G., and Smith, A.D.
Canada Department of Agricultural Research Stations, Lethbridge, Alberta
Journal of Environmental Quality, Vol 2, No 1, p 112-115, January-March, 1973. 5 fig, 3 tab, 14 ref.

Descriptors: *Water pollution sources, *Nitrogen, *Grasslands, Grasses, Leaching, Nutrient removal, Leaching, Canada, Salinity, Groundwater, Fertilizers.

The downward movement of NO3-N in dryland soils under native grass 6 to 8 years after N was applied at rates up to 976 kg/ha reached a depth of 180 cm. Phosphorus fertilizer did not affect NO3-N movement. Under seeded grasses, there was no evidence of NO3-N accumulation 2 years after a single application of N at rates up to 944 kg/ha. After repeated annual applications of N that totaled up to 3776 kg/ha over a 4-year period, NO3-N accumulations were found to depths of 90 to 120 cm. The depth of NO3-N movement under bromegrass was similar to that under crested wheatgrass, but more NO3-N accumulated in the soil under the bromegrass. In irrigated soil underlaid by drains, NO3-N leaching was greater in a loam soil over till growing a mixture of bromegrass and alfalfa than in a loam soil over sandy loam-loamy sand growing an irrigated pasture-grass mixture. These studies indicated that, with good management, fertilizer N on grassland soils is not an important contributor to pollution in semiarid southern Alberta.

72-73:05B-046
CHEMICAL AND BIOCHEMICAL CONSIDERATIONS FOR MAXIMIZING THE EFFICIENCY OF FERTILIZER NITROGEN,
Parr, J.F.
United States Department of Agriculture, Agricultural Research Service, Baton Rouge, Louisiana.
Journal of Environmental Quality, Vol 2, No 1, p 75-84, January-March, 1973. 6 fig, 2 tab, 56 ref.

Descriptors: *Water pollution sources, *Nitrogen, *Fertilizers, Nutrient removal, Leaching, Salinity, Nitrates, Nitrification, Groundwater.

Fertilizer nitrogen is subject to loss from the soil-root zone, and immobilization by the soil and rhizosphere microfloras, which can result in low recovery and use efficiency of the applied nitrogen. With increasing rates of application, fertilizer nitrogen efficiency decreases progressively, while leaving an increasing amount of unused nitrogen as a potential pollution hazard. Since the point of greatest economic return from this nutrient is usually somewhere below the point of maximum yield, it should be possible to adjust fertilizer nitrogen rates for maximum return and minimum loss to the environment. This can be achieved through improved soil and crop management practices, including proper timing of application of conventional nitrogen fertilizers and use of deep-rooted crops for recovery of leached nitrate. Efficiency of fertilizer nitrogen might also be increased with controlled release fertilizers, including the use of coated granules, and compounds of limited water solubility blended with conventional nitrogen fertilizers.

72-73:05B-047

AGRICULTURAL CHEMICALS IN RELATION TO ENVIRONMENTAL QUALITY: CHEMICAL FERTILIZERS, PRESENT AND FUTURE,

Nelson, L.B.
Tennessee Valley Authority, Office of Agricultural and Chemical Development, Muscle Shoals, Alabama.
Journal of Environmental Quality, Vol 1, No 1, p 2-6, January-March, 1972.
15 ref.

Descriptors: *Water pollution sources, *Fertilizers, *Leaching, Nutrient removal, Runoff, Erosion, Agricultural chemicals, Nitrogen, Phosphorus, Potassium.

In the USA, fertilizers have accounted for over 50% of the increase in crop production since 1940, and farmers have substituted fertilizers for land and other inputs. However, considerable controversy has developed in recent years over the role of fertilizers in pollution of natural waters. Increased nitrate and phosphate levels in waters are cited by ecologists as proof of contamination by fertilizers, but this is contested by many agriculturists. Examination by competent reviewers of the limited data available so far indicates that losses of fertilizer nutrients into surface and groundwaters may be minimal under most situations. There are a number of ways to minimize losses without sacrificing the important benefits gained from fertilizers. These include carefully tailoring rates and times of nitrogen application to better fit the needs of the growing crop, greater care in irrigation, use of slow-release nitrogen fertilizers, and wider application of selected soil conservation practices to control surface losses of both nitrates and phosphates.

72-73:05B-048

FATE OF NITRATE FROM MANURE AND INORGANIC NITROGEN IN A CLAY SOIL CROPPED TO CONTINUOUS CORN,

Kimble, J.M., Bartlett, R.J., McIntosh, J.L., and Varney, K.E.
Vermont University, Department of Plant and Soil Science, Burlington.
Journal of Environmental Quality, Vol 1, No 4, p 413-415, October-December, 1972. 5 fig, 1 tab, 6 ref.

Descriptors: *Water pollution sources, *Nitrogen, *Nutrient removal, Denitrification, Leaching, Nitrogen cycle, Fertilizers, Nitrates.

Effects of dairy manure and N fertilizer were studied on plots that had received in a factorial arrangement two levels of manure (0 and 66 metric tons/ha) and two levels of N (0 and 224 kg/ha) applied every spring for 6 years. Laboratory incubation studies using soil profile samples showed potential denitrification to be greater in soil from the manure treated plots than in plots receiving either inorganic N or no N. The amount decreased with depth to 96 cm, below which energy for anaerobic microbial activity appeared to be limiting. Laboratory analyses of profile samples indicated decreasing nitrate-N/chloride ratios at all depths from fall to spring, suggesting that denitrification rather than leaching was responsible for a significant portion of the nitrate loss during this period. Abrupt decreases in the nitrate-N/chloride ratios from the surface to the 45- to 71-cm depth indicated that denitrification had taken place and that a nitrate bulge at 96- to 122-cm probably was caused by denitrification above that depth.

72-73:05B-049

INCREASED DENITRIFICATION IN SOILS BY ADDITIONS OF SULFUR AS AN ENERGY SOURCE,

Mann, L.D., Focht, D.D., Joseph, H.A., and Stolzy, L.H.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Journal of Environmental Quality, Vol 1, No 3, p 329-332, July-September, 1972.
1 fig, 6 tab, 18 ref.

Descriptors: *Denitrification, *Soil amendments, *Leaching, Nutrient removal, Water pollution sources, Reduction, Oxidation.

Denitrification rates were studied in four large soil columns using Hanford sand loam and Moreno silty clay loam soils. One column of each soil was amended with sulfur to serve as an energy source for the bacterium Thiobacillus denitrificans. Limestone was also added as a pH buffer. The other column of each soil was left untreated to serve as a control. A solution of $Ca(NO_3)_2$ containing 425 ppm NO_3-N was perfused continuously through the columns. The columns were monitored periodically at depths of 10, 30, 50, 70, and 90 cm for nitrate, nitrite, redox potential and microbial numbers. Highly anaerobic conditions developed in all columns. All of the nitrate was reduced in each column, and nitrates penetrated to lower depths in the untreated columns. Nitrite concentrations were found to be negligible Sulfur additions to field soils which are low in microbial energy sources could be an effective method of reducing the nitrate level in waters percolating through the profile.

72-73:05B-050
NITRATE IN UNSATURATED ZONE OF AN ALLUVIAL SOIL IN RELATION TO FERTILIZER NITROGEN RATE AND IRRIGATION LEVEL,
Adriano, D.C., Pratt, P.F,, and Takatori, F.H.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Journal of Environmental Quality, Vol 1, No 4, p 418-422, October-December, 1972. 5 fig, 3 tab, 10 ref.

Descriptors: *Water pollution sources, *Fertilizers, *Nitrates, Nutrient removal, Leaching, Asparagus, Unsaturated flow, Nitrogen cycle, Denitrification.

Soil samples to the 15-m depth beneath asparagus and celery were taken to determine the NO_3 concentration in the solution of the unsaturated zone and to estimate the soil N balance. Transit time for water to move to the 15-m depth was calculated from drainage volumes and volumetric water contents. Nitrogen balance was calculated from data for N input, N removal in harvested crops, and water records for the calculated transit time. The NO_3 concentration in the unsaturated zone increased with increase in N rate but was inversely related to the leaching volume. Denitrification was assumed to be the cause of the low efficiency of recycling N by these crops. The data suggest that high rates of N combined with high levels of water use are conducive to denitrification in relatively permeable soils.

72-73:05B-051
A SIMPLE DIGESTION PROCEDURE FOR ESTIMATION OF TOTAL NITROGEN IN SOILS AND SEDIMENTS,
Nelson, D.W., and Sommers, L.E.
Purdue University, Department of Agronomy, Lafayette, Indiana.
Journal of Environmental Quality, Vol 1, No 4, p 423-425, October-December, 1972. 5 tab, 12 ref.

Descriptors: *Digestion, *Nitrogen, Nutrients, Fertility, Soils, Soil chemistry, Soil investigations.
Identifiers: Kjedahl, Steam distillation, Hydrofluoric acid.

A simple and convenient digestion procedure for total N analysis of soils and sediments is described. The digestion is carried out in pyrex Folin-Wu tubes heated in [illegible] luminum block placed on a hot plate. Samples up to 1 g in size may be used and a digestion time of three hours after clearing is adequate. The proposed and conventional semimicro-Kjeldahl methods gave essentially the same values for total N in a wide variety of soils and sediments. The precision of the proposed method was almost as good as those reported for other semimicro-Kjeldahl methods. The tube digestion method allows simultaneous digestion of 60 samples in a relatively inexpensive and maintenance-free aluminum heating block, which occupies a minimum of laboratory space and appears applicable for routine determination of total n in soils having diverse properties.

72-73:05B-052
CONCENTRATIONS OF NITROGEN, PHOSPHORUS, POTASSIUM, AND TOTAL SOLUBLE SALTS IN SOIL SOLUTION SAMPLES FROM FERTILIZED AND UNFERTILIZED HISTOSOLS,
Hortenstine, C.C. and Forbes, R.B.
Florida University, Soil Science Department, Gainesville.
Journal of Environmental Quality, Vol 1, No 4, p 446-449, October-December, 1972. 5 fig, 9 ref.

Descriptors: *Water pollution sources, *Runoff, Surface runoff, Subsurface runoff, Agricultural runoff, Nitrogen, Phosphorus, Potassium, Nutrient removal, Peat.

Lake Apopka ranked at one time among the most productive bass and panfish bodies of water in the United States. During recent years this lake became eutrophic and fishing declined drastically. Farming operations on the rich organic soil along the northern shore of the lake were implicated as one cause of this eutrophication. To measure agriculture's contributions to the nutrient concentration in the lake, soil solution samples were extracted from uncleared, swampy Everglades mucky peat; newly cleared, drained Everglades mucky peat; and Everglades mucky peat that had been under cultivation for approximately 15 years. Nitrate-N, orthophosphate P, and K concentrations were relatively low in soil solution samples from the swampy area. Concentrations of each nutrient in soil solution extracted at the 60-cm depth in the newly cleared area increased by as much as 8 to 12 times as compared to the 60-cm depth in the swampy area. Further increases were noted in the cultivated area. Indications were that the peat itself was a heavy contributor of nutrients to the drainage water.

72-73:05B-053
NITROGEN-15 ENRICHMENT OF SOILS AND SOIL-DERIVED NITRATE,
Bremner, J.M., and Tabatabai, M.A.
Iowa State University, Department of Agronomy, Ames.
Journal of Environmental Quality, Vol 2, No 3, p 363-365, July-September, 1973. 3 tab, 12 ref.

Descriptors: *Nitrates, *Nitrogen, Leaching, Nutrient removal, Water pollution sources, Radioisotopes.
Identifiers: Nitrogen-15, Soil-derived nitrate

Nitrogen-isotope analysis of soils and soil-derived nitrate showed that there is considerable variation in the N15 enrichment of the nitrate nitrogen produced on aerobic incubation of different soils and that the N15-enrichment of this nitrate nitrogen depends upon the time of incubation and can differ markedly from that of the total soil N. The data reported illustrate the impracticability of a recently proposed method of assessing the contribution of fertilizers to nitrate in surface waters that requires measurement of the natural N15 enrichment of soil- and fertilizer-derived nitrate.

72-73:05B-054
NITROGEN TRACERS IN NITROGEN CYCLE STUDIES - PAST USE AND FUTURE NEEDS,
Hauck, R.D.
Tennessee Valley Authority, Division of Agricultural Development, Muscle Shoals, Alabama.
Journal of Environmental Quality, Vol 2, No 3, p 317-327, July-September, 1973. 2 tab, 56 ref.

Descriptors: *Nitrogen cycle, *Nitrogen compounds, Nitrogen fixation, Radioisotopes, Nutrient removal, Leaching, Water pollution sources, Nitrates.

To achieve N balance in productive ecosystems, better quantitative estimates of N transformation rates are needed. Nitrogen tracers are indispensable for making many of these estimates. Either N15-depleted or N15-enriched materials can be used. The use of N15-depleter materials is limited to studies where dilution from other N is less than 2,000-fold, but these materials are potentially available in ton amounts. Use of variations in natural N15 abundance may be useful in observing qualitative relationships among N cycle processes over large areas or extremely long time periods. Such use is questionable for obtaining quantitative information for short-term N transformation processes. Obvious information gaps are quantitative data on atmospheric N2 fixation and denitrification in cropped field soils and N transformation data for many other ecosystems. A program for computer data retrieval and correlation is outlined.

72-73:05B-055
DISTRIBUTION AND CHEMISTRY OF PHOSPHORUS IN AN ALBAQUALF SOIL AFTER 82 YEARS OF PHOSPHATE FERTILIZATION,
Kao, C. W., and Blanchar, R. W.
Missouri Agricultural Experiment Station.
Journal of Environmental Quality, Vol. 2, No. 2, p 237-240, April-June, 1973.
2 fig, 3 tab, 25 ref.
(See 72-73:02G-055)

72-73:05B-056
PLANT NUTRIENT CONCENTRATIONS IN RUNOFF FROM FERTILIZED CULTIVATED EROSION PLOTS AND PRAIRIE IN EASTERN SOUTH DAKOTA,
White, E. M., and Williamson, E. J.
South Dakota State University, Plant Science Department, Brookings.
Journal of Environmental Quality, Vol. 2, No. 4, p 453-455, October-December, 1973. 3 tab, 6 ref.

Descriptors: *Water pollution sources, *Water pollution control, *Nutrient removal, Agricultural runoff, Fertilizers, Nitrogen, Phosphorus, Surface runoff, Rainfall-runoff relationships.

Runoff waters from fertilized erosion plots and from native prairie in South Dakota were compared to determine the effect agriculture has had on water quality. Calcium, Mg, K, Na, total P, PO4-P, NO3-N, and NH4-N contents were found to be similar in runoff from the erosion plots and from the pririe. The elemental contents in runoff from erosion plots planted to oats and alfalfa or fallowed were not distinctly different and varied from year to year. Variations in the ions in water collected from different basins in the prairie may be caused by differences in the prairie vegetation and mulch in the drainage basins, in the time the runoff has to dissolve ions because of different overland flow distances, and in the dilution of the runoff by precipitation that falls directly into the basin. Losses of plant nutrients in soil eroded from cultivated land may be similar to average losses that would occur naturally if the area were in pristine prairie that was periodically subjected to fire.

72-73:05B-057
LONG-TERM EFFECTS OF MANURE, FERTILIZER, AND PLOW DEPTH ON CHEMICAL PROPERTIES OF SOILS AND NUTRIENT MOVEMENT IN A MONOCULTURE CORN SYSTEM,
Vitosh, M. L., Davis, J. F., and Knezek, B. D.
Michigan Agricultural Experiment Station, Crop and Soil Science Department, East Lansing.
Journal of Environmental Quality, Vol. 2, No. 2, p 296-299, April-June, 1973.
5 tab, 20 ref.

Descriptors: *Animal wastes (wildlife), *Farm wastes, *Fertilizers, Solid wastes, Organic matter, Nutrient removal.

An evaluation of soil chemical properties, organic matter and nutrient accumulations, and nutrient movement and recovery after 6 and 9 years of annual fertilizer and manure applications to continuous corn was conducted on two soil types. Plow depths of 18 versus 30 cm had little or no effect on soil test values or nutrient accumulation patterns in the surface of a Conover-Hodunk loam soil. The pH value of both soils decreased slightly more than 0.1 pH unit per year with the annual application of 168 kg of N/ha as ammonium sulfate. The most favorable rate of manure for the Metea sandy loam soil was found to be 22.4 metric tons/ha (10 tons/acre). Larger applications caused a significant buildup of exchangeable K in the surface and subsurface horizons and resulted in inefficient use of all nutrients. The K buildup was less critical on the loam soil or where silage rather than grain was removed.

72-73:05B-058
NITROGEN LOSSES IN SURFACE RUNOFF FROM AGRICULTURAL WATERSHEDS ON MISSOURI VALLEY LOESS,
Schuman, G. E., Burwell, R. E., Piest, R. F., and Spomer, R. G.
United States Department of Agriculture, Agricultural Research Service, Lincoln, Nebraska.
Journal of Environmental Quality, Vol. 2, No. 2, p 299-302, April-June, 1973.
5 tab, 15 ref.

Descriptors: *Nitrogen, *Leaching, *Nutrient removal, Solubility, Pollutants, Soil chemistry, Dispersion, Fertilizers, Sediments, Erosion.

Nitrogen losses from surface runoff from four field-size (30 to 60.8 ha) watersheds in southwestern Iowa, near Treynor, were measured during 1969, 1970, and 1971. A contour-planted corn watershed and a pasture watershed were fertilized at the recommended N rate (168 kg/ha). A level-terraced and a contour-planted corn watershed were fertilized at 2.5 times this rate. The conservation practice of level-terraced corn or pasture was very effective in reducing water, sediment, and N yields when compared with the contour-planted corn watersheds. Annual water-soluble N losses were low from all watersheds. The three-year average annual solution N loss from the contour-planted corn watershed, fertilized at 2.5 times the recommended rate, was 3.05 kg/ha; the comparable watershed, fertilized at the recommended rate, lost only 1.89 kg/ha.

72-73:05B-059
EXPERIMENTAL AND PREDICTED MOVEMENT OF THREE HERBICIDES IN A WATER-SATURATED SOIL,
Davidson, J. M., and McDougal, J. R.
Oklahoma State University, Agronomy Department, Stillwater.
Journal of Environmental Quality, Vol. 2, No. 4, p 428-433, October-December, 1973. 7 fig, 1 tab, 19 ref.

Descriptors: *Water pollution sources, *Herbicides, Adsorption, Dispersion, Pore water.
Identifiers: Equilibrium adsorption, Herbicide movement.

The equilibrium adsorption characteristics of 1, 1-dimethyl-3-urea, 4-amino-3,5, 6-trichloropicolinic acid, and 2, 4-bis-6-s-triazine on Ca-saturated Norge loam soil were measured and were found to fit the Freundlich equation. A solution of each herbicide was displaced through a water-saturated column of Norge loam soil at various average pore-water velocities and effluent samples evaluated to determine the importance of adsorption kinetics to the mobility of the herbicide. The displacement of each herbicide through the soil was significantly influenced by the average pore-water velocity. The use of a kinetic adsorption model in a convective transport equation did not adequately predict the shape of the effluent concentration distribution at the high pore-water velocities, but did give the left-hand shift exhibited by the data. Equilibrium adsorption and desorption isotherms were measured for picloram on Ca-saturated Norge loam soil.

72-73:05B-060

BIONOMICS AND INTEGRATED CONTROL OF PLANT PARASITIC NEMATODES,

Good, J. M.

United States Department of Agriculture, Agricultural Research Service, Beltsville, Maryland.

Journal of Environmental Quality, Vol. 1, No. 4, p 382-386, October-December, 1972. 1 tab, 41 ref.

Descriptors: *Nematodes, *Nematocides, Cultivation, Entomology, Microbiology, Soil microorganisms, Soil sterilants, Water pollution sources.

Establishment of an agroecosystem promotes the rapid increase of endemic pathogenic species and allows introduction of nonendemic species that quickly establish dominance. Nematodes now cause about 10% loss of yields of crops in the United States. About 20 highly effective nematicides are available to control nematodes and associated plant diseases in a number of crops. Nematode populations can be regulated by a number of soil management practices, including clean transplant, seed production, and crop rotations. Biological control can be achieved by addition of various types of organic matter to soil, some of which are not presently utilized, especially biodegradable solid waste. Over 152 nematode-resistant crop varieties representing 17 major crops are available with resistance from one to three species of the 10 most destructive nematode types. Physical methods of control, including quarantine, sanitation, and crop destruction, are not vigorously applied.

72-73:05B-061

ISOTOPE FRACTIONATION OF N15 and N14 IN MICROBIOLOGICAL NITROGEN TRANSFORMATIONS: A THEORETICAL MODEL,

Focht, D. D.

California University, Department of Soil Science and Agricultural Engineering, Riverside.

Journal of Environmental Quality, Vol. 2, No. 2, p 247-252, April-June, 1973. 2 fig, 1 tab, 29 ref.

Descriptors: *Nitrogen, *Fertilizers, *Isotope fractionation, Isotope studies, Stable isotopes, Analytical techniques.

The kinetics for first-order multisequence reactions are derived for microbial fractionation of N14 and N15 isotopes. The isotope effect accounts for unreacted substrate becoming progressively enriched in the heavier isotope due to preferential utilization of the lighter isotope by microorganisms. Consequently, during denitrification nitrate becomes enriched in N15 as its concentration diminishes. This inverse proportional relationship is expressed as a hyperbolic function. Similar curves are derived for nitrate originating from ammonification and/or nitrification. Regression coefficients for a straight line approximation are better than -0.98, but not as good as the actual coefficients for the derived hyperbolic equations. A negative regression "line" for nitrate occurs for all denitrification reactions during isotope discrimination.

72-73:05B-062
AGRICULTURAL CHEMICALS IN SURFACE RUNOFF, GROUND WATER, AND SOIL: I. ENDRIN,
Willis, G. H., and Hamilton, R. A.
United States Department of Agriculture, Agricultural Research Service, Baton Rouge, Louisiana.
Journal of Environmental Quality, Vol. 2, No. 4, p 463-466, October-December, 1973. 4 tab, 11 ref.

Descriptors: *Water pollution sources, *Agricultural chemicals, *Pesticides, Runoff, Subsurface runoff, Surface runoff, Groundwater.

Endrin was surface applied at a rate of 0.337 kg/ha to sugarcane plots instrumented to sample surface runoff and groundwater. Runoff, groundwater, and soil samples were collected over a two-year period and analyzed for endrin. Only small amounts of endrin were lost annually in runoff (less than 0.2% of that applied), and little endrin accumulated in soil. Trace amounts of endrin appeared to move through soil in the plots but not through soil columns. A delay of 72 hours between application and rainfall decreased the amount of endrin in runoff, groundwater, and soil.

72-73:05B-063
MINIMIZING NITRATE SEEPAGE FROM THE HULA VALLEY INTO LAKE KINNERET (SEA OF GALILEE): I. ENHANCEMENT OF NITRATE REDUCTION BY SPRINKLING AND FLOODING,
Raveh, A., and Avnimelech, Y.
Israel Institute of Technology, Soil and Fertilizer Laboratory, Haifa.
Journal of Environmental Quality, Vol. 2, No. 4, p 455-458, October-December, 1973. 3 fig, 4 tab, 11 ref.

Descriptors: *Water pollution sources, *Nutrient removal, *Nitrates, Denitrification, Nutrient removal, Fertilizers, Irrigation practices, Sprinkler irrigation, Surface irrigation, Flood irrigation.

Decomposition of organic matter in the drained soils of the Hula Valley leads to the accumulation of nitrates. These are leached during the rainy season to the Jordan River and endanger Lake Kinneret. Field studies have shown that nitrates can be reduced through the use of the irrigation systems existing in the area. A treatment of either sprinkling or flooding by raising the water table reduced the nitrate concentration to about half of its original amount. Both treatments induced anaerobic conditions in the soil and reduced the nitrate contents, probably by denitrification. The efficiency of the reduction depends on the existence of labile organic substrates in the soil.

72-73:05B-064
A STUDY OF FACTORS INFLUENCING THE NITROGEN AND PHOSPHORUS CONTENTS OF NEBRASKA WATERS,
Muir, J., Seim, E. C., and Olson, R. A.
Nebraska University, Agricultural Experiment Station, Lincoln.
Journal of Environmental Quality, Vol. 2, No. 4, p 466-470, October-December, 1973. 1 fig, 5 tab, 14 ref.

Descriptors: *Nitrogen, *Phosphorus, *Fertilizers, Phosphates, Nutrient removal, Pollutants, Water pollution, Water pollution sources, Irrigation, Streams, Groundwater.

Correlation studies reveal little relation between N and P concentrations of the water and agricultural use of fertilizers. Nutrient levels in the water are governed more by human and livestock densities and intensity of irrigation development than by agronomic production factors. Only at sites of intensive irrigation development on very sandy soils and with irrigation of valley positions of shallow water table has fertilizer N contributed substantially to reduction in groundwater quality. Nutrient concentrations in streams fluctuate widely with (i) varied time and rate of organic waste intrusions and subsequent biological assimilation and (ii) major runoff events. Reservoirs on streams also have a major modifying action in reducing sediment and fertility load. The observed higher N content of streams during periods of peak flow can be attributed partially to the high N content of precipitation and its direct runoff into streams during periods of high rainfall intensity.

72-73:05B-065
THE PERSISTENCE AND MOVEMENT OF PICLORAM AND 2, 4, 5-T IN SOILS,
Lutz, J. F., Byers, G. E., and Sheets, T. J.
North Carolina State University, Agricultural Experiment Station, Raleigh.
Journal of Environmental Quality, Vol. 2, No. 4, p 485-488, October-December, 1973. 1 fig, 5 tab, 24 ref.

Descriptors: *Herbicide, *2,4,5-T, *Leaching, Pesticide kinetics, Pollutants, Water pollution, Defoliants, Weed control, Soil properties, Soil chemistry, Soil physics.

The movement and persistence of picloram (4-amino-3,5,6-trichloropicolinic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) were studied on a western North Carolina watershed on which extensive agronomic, hydrologic, and climatic data had been accumulated over a period of 18 years. Picloram was more persistent than 2,4,5-T; approximately 60% of the picloram and 90% of the 2,4,5-T disappeared in 15 days. There was some penetration into the soil, but a very high percentage of the total amount present at the different sampling periods was in the 0- to 7.5-cm layer. Doubling the application rate (4.48 vs. 2.24 kg/ha) resulted in a two-fold increase in the amount of herbicide recovered at each sampling period. Very little downslope movement of either herbicide occurred even though the average slope on the plots was approximately 27%. Practically no herbicide was found more than 0.3 m, and none beyond 1.2 m, downslope. More picloram than 2,3,5-T moved.

72-73:05B-066
NITROGEN AND PHOSPHORUS COMPOSITION OF SURFACE RUNOFF AS AFFECTED BY TILLAGE METHOD,
Romkens, M. J. M., Nelson, D. W., and Mannering, J. V.
United States Department of Agriculture, Lafayette, Indiana.
Journal of Environmental Quality, Vol. 2, No. 2, p 292-295, April-June, 1973. 2 fig, 4 tab, 12 ref.
(See 72-73:02E-011)

72-73:05B-067
AGRICULTURAL RUNOFF-CHARACTERISTICS AND CONTROL,
Loehr, R. C.
Cornell University, Ithaca, New York, Department of Civil and Agricultural Engineering.
Journal of the Sanitary Engineering Division, American Society of Civil Engi-

greater than from oxamide; but by the third harvests, yield responses and N uptake from oxamide were greater than from urea. Of the N added in urea in the first experiment, 51% was recovered in the crops and 28% was still in the soil (0-25cm) at the end of the growing season. Corresponding figures for oxamide were 52% in the crops and 31% in the soil. In the second experiment, when fertilizer applications and planting operations were delayed until more favorable growing weather, 93% and 99% of the urea- and oxamide-N, respectively, were estimated as recovered in the crops.

72-73:05B-073
APPLIED AND RESIDUAL NITRATE-NITROGEN EFFECTS ON IRRIGATED GRAIN SORGHUM YIELD,
Onken, A. B., and Sunderman, H. D.
Texas A & M University, Lubbock.
Soil Science Society of America Proceedings, Vol. 36, No. 1, p 94-97, January-February, 1972. 4 tab, 14 ref.
(See 72-73:02G-133)

72-73:05B-074
PRIMING EFFECT OF N-15 LABELED FERTILIZERS ON SOIL NITROGEN IN FIELD EXPERIMENTS,
Westerman, R. L., and Kurtz, L. T.
Arizona University, Tucson.
Soil Science Society of America Proceedings, Vol. 37, No. 5, p 725-727, September-October, 1973. 1 tab, 15 ref.
(See 72-73:02G-135)

72-73:05B-075
NITROGEN AND PHOSPHORUS LOSSES IN SURFACE RUNOFF FROM AGRICULTURAL LAND AS INFLUENCED BY PLACEMENT OF BROADCAST FERTILIZER,
Timmons, D. R., Burwell, R. E., and Holt, R. F.
United States Department of Agriculture, Agricultural Research Service, North Central Soil Conservation Research Center, Morris, Minnesota.
Water Resources Research, Vol. 9, No. 3, p 658-667, June, 1973. 6 fig, 3 tab, 26 ref.

Descriptors: *Nutrient removal, *Leaching, *Fertilizers, Nitrogen, Phosphorus, Fallowing, Erosion, Water pollution sources.

Nitrogen (N) and phosphorus (P) losses were determined in the sediment and water components of surface runoff from fertilized and unfertilized plots on a Barnes loam soil located in west-central Minnesota. Simulated rainfall was used to cause surface runoff from small fallow plots that received uniform amounts of N and P but that had a different placement of the broadcast fertilizer. Deep incorporation of the fertilizer by plowing down (and subsequent disking) caused N and P losses about equal to those in surface runoff from unfertilized plots. The highest nutrient losses occurred when the fertilizer was broadcast on a disked surface.

72-73:05B-076
MINERAL SPRINGS IN THE SUEZ RIFT VALLEY - COMPARISON WITH WATERS IN THE JORDAN RIFT VALLEY AND POSTULATION OF A MARINE ORIGIN,
Mazor, E., Nadler, A., and Molcho, M.

Israel Atomic Energy Commission, Nuclear Research Center, Nahal Soreq, Israel.
Journal of Hydrology, Vol. 20, No. 4, p 289-309, December, 1973. 6 fig, 4 tab, 15 ref.

Descriptors: *Water quality, *Water types, Water analysis, Water chemistry, Water pollution sources.

Fresh and mineral waters from the eastern margin of the Suez Rift Valley are described. They include a fair number of sources that resemble the mineral waters in the Jordan Rift Valley. The term Tiberias-Farun water is thus suggested to describe them. They are characterized compositionally by Cl>Na, the presence of NaCl and MgCl2, a Cl/Br ratio around 150, elevated radium and H2S content, elevated temperature, a light stable-isotope composition and high carbon-14 age. The Tiberias-Farun waters are suggested to have originated from entrapped seawater that gradually changed in composition by interaction with aquifer rocks. Such changes were demonstrated to take place in the laboratory experiments.

72-73:05B-077
NITROGEN NUTRITION AND YIELD RELATIONS OF NUGAINES WINTER WHEAT,
Laopirojana, P., Roberts, S., and Dawson, M. D.
Washington State University, Agricultural Research and Extension Center, Prosser.
Agronomy Journal, Vol. 64, No. 5, p 571-573, September-October, 1972. 1 fig, 2 tab, 12 ref.

Descriptors: *Nutrient removal, *Crop response, *Nitrogen, Wheat, Fertility, Fertilization, Crop production.

A nitrogen rate study was undertaken to determine the potential utility of the critical nutrient concept as a guide to N fertilization of winter wheat, as part of a more extensive soil fertility investigation in western Oregon. This work on wheat was prompted by the need for a suitable diagnostic technique for determining more precisely the optimum levels of available N. A graph of grain yield vs NO3-N concentration in plant leaves at jointing showed a definite peak in grain yield at approximately 500 ppm NO3-N in the leaves. Additional applied N very readily increased leaf NO3-N considerably above 500 ppm and caused a slight, insignificant drop in grain yield. These results suggest the applicability of the critical nutrient concept to semidwarf wheat, and provide justification for additional work to establish more precisely the critical level for NO3-N in wheat.

72-73:05B-078
EXPECTATIONS, VARIANCES, AND SENSITIVITY OF NET RETURNS FROM CORN FERTILIZATION EXPERIMENTS,
Ogut, C., Doll, J. P., Kroth, E. M., and Colyer, D.
Missouri University.
Agronomy Journal, Vol. 64, No. 4, p 515-518, July-August, 1972. 1 fig, 3 tab, 8 ref.

Descriptors: *Nutrient removal, *Crop response, *Nitrogen, Corn, Fertility, Fertilization, Crop production.

A series of experiments measuring corn yield response to applied N and plant population were conducted at three locations for several years in northern Missouri. Expected profit functions were estimated for each experiment and the input amounts that would have maximized profits for the time period of the experiments were derived. The resulting amounts were 197 kg of N and 45,360 plants/ha for Grundy County, 140 kg of N and 40,488 plants for Saline County, and 135 kg of N and 34,455 plants in Boone County. These amounts were lower than many of the annual optima. Furthermore, expected profits over the experimental periods were relatively insensitive to departures from the annual optima. Additional analyses determined input rates that (i) minimized the cost or (ii) minimized the variance of a fixed expected profit level for the period.

72-73:05B-079
INFLUENCE OF NITROGEN, PHOSPHORUS, AND PLANT POPULATION ON YIELD AND QUALITY OF FORAGE CORN,
Robinson, D. L., and Murphy, L. S.
Louisiana State University, Department of Agronomy, Baton Rouge.
Agronomy Journal, Vol. 64, No. 3, p 349-351, May-June, 1972. 4 tab, 14 ref.

Descriptors: *Corn, *Fertility, *Crop response, Nitrogen, Phosphorus, Nutrient removal, Crop production, Plant populations.

Irrigated forage corn was grown at five plant populations and five levels each of N and P at five field locations in central Kansas during a 3-year period to determine the influence of each variable on yield and quality of forage produced. An incomplete factorial arrangement of 23 treatments was used in a randomized complete block design. Multiple regression analyses indicated both forage and grain yields were significantly affected by N but not by P or plant population treatments. Treatment variables contributed little to variability in forage quality as measured by in vitro fermentation and forage fiber analyses. Nitrogen, cellulose, and lignin concentrations in the forage contributed up to 84% of the variation in in vitro dry matter digestibility. These results indicate that in central Kansas, irrigated corn yields are primarily a function of the rate of N application, and that a rather wide range of plant populations can be tolerated without significantly affecting yield or quality of forage produced.

72-73:05B-080
RECOVERY, RESIDUAL EFFECTS, AND FATE OF NITROGEN FERTILIZER SOURCES IN A SEMI-ARID REGION,
Power, J. F., Alessi, J., Reichman, G. A., and Grunes, D. L.
Northern Great Plains Research Center, Mandan, North Dakota.
Agronomy Journal, Vol. 65, No. 5, p 765-768, September-October, 1973. 2 fig, 3 tab, 13 ref.

Descriptors: *Nutrient removal, *Leaching, *Nitrogen, Fertilizers, Nitrates, Crop response, Water pollution sources.

In a field experiment four fertilizer N sources were applied to separate areas of corn and bromegrass for four years. From the fifth through seventh years, the two areas were uniformly seeded to barley without additional N fertilization, until residual effects were no longer significant. Sources of N used were ammonium sulfate, ammonium nitrate, calcium nitrate, and urea, applied at either 55 or 110 kg/ha to Parshall fine sandy loam. Recovery of fertilizer N in corn plant tops was greatest for ammonium nitrate. Over 35% of the calcium nitrate and urea applied at 110 kg/ha of N to corn was leached below the root zone. Leaching of fertilizer N applied to bromegrass was insignificant. Except for urea, fertilizer N recovery by bromegrass from the other N sources was nearly equal and usually higher at 55 kg/ha. Residual growth responses were smaller from N applied to bromegrass than to corn.

72-73:05B-081

LEACHING LOSSES OF SULFUR DURING WINTER MONTHS WHEN APPLIED AS GYPSUM, ELEMENTAL S OR PRILLED S,

Rhue, R. D., and Kamprath, E. J.

North Carolina State University, Agricultural Experiment Station, Raleigh.

Agronomy Journal, Vol. 65, No. 4, p 603-605, July-August, 1973. 4 fig, 2 tab, 12 ref.

Descriptors: *Sulfates, *Sulfur, Sulfur compounds, Gypsum, Inorganic compounds, Leaching, Water pollution sources.

Interest has developed in the use of elemental sulfur as a means of maintaining an adequate supply of sulfur where leaching is a problem. Studies were conducted with gypsum, finely divided elemental sulfur, and prilled sulfur on a Wagram loamy sand and a Georgeville silty clay loam to determine the levels of sulfate sulfur resulting from additions of these sources. Sulfate contents of the 0 to 15-, 15 to 30- and 30 to 45-cm depths were determined at various times over a period of 200 days after the different sulfur sources were applied in October. Almost all of the sulfate, that added as gypsum and that resulting from the oxidation of elemental sulfur, had been leached from the top 45 cm of the Wagram soil 180 days after application. There was essentially no movement of sulfate, however, in the Georgeville soil. Very little oxidation of prilled sulfur appeared to be occurring to any extent in either soil.

72-73:05B-082

RESPONSE OF SUBIRRIGATED HAY MEADOWS TO THE APPLICATION OF NITROGEN, PHOSPHORUS, AND SULFUR,

Rehm, G. W., Moline, W. J., Sorensen, R. C., and Burzlaff, D. F.

Nebraska University, Northeast Station, Concord.

Agronomy Journal, Vol. 65, No. 4, p 665-668, July-August, 1973. 4 fig, 7 tab, 7 ref.

Descriptors: *Fertilizers, *Nitrogen, *Phosphorus, Fertility, Hay, Yield equations.

This study was designed to evaluate the effect of five rates of N, P and S on the yield and grass-legume composition of subirrigated meadows. Forage yields were recorded and separations made to determine grass-legume composition. Yields increased linearly with applied N while the response to P was curvilinear. There was no response to S. The percentage of grass in the meadows increased with applied N. Legume percentages increased with added P. Grass yields showed a linear increase with applied N and a curvilinear response to added P. Legume yields decreased linearly at low P rates when high rates of N were applied but increased curvilinearly as P rates were increased. Throughout the study, combinations of N and P produced the highest yields, thus demonstrating the importance of the combination of these two nutrients for maximum production from subirrigated hay meadows.

72-73:05B-083

CATION TRANSPORT IN SOILS AND FACTORS AFFECTING SOIL CARBONATE SOLUBILITY,

Jurinak, J. J., Lai, S. H., and Hassett, J. J.
Environmental Protection Technology Series Report No. EPA-R2-73-235, May 1973.
87 p, 23 fig, 4 tab, 31 ref, append.

Descriptors: *Ion transport, *Calcium carbonate, Leaching, Cation exchange, Irrigation, Return flow, Chemical precipitation, Hardness (Water), Solutes, Solubility.
Identifiers: *Solute transport, *Carbonate solubility, Miscible displacement, Carbonate saturometer.

A predictive model of cation transport in soils undergoing miscible displacement was developed and tested. A mass balance equation was formulated to include a general nonlinear cation exchange function. The model was applied to the transport of cations through an exchanger using five types of exchange functions. The model was further tested by conducting soil column studies which involved both homovalent and heterovalent exchange. Good agreement between experimental and predicted data was obtained. Laboratory studies were also conducted to assess the affect of Mg+2 ion on the solubility of calcareous materials. Solubility was found to vary with the surface area and mineralogy of the carbonate material, and the degree of saturation of the water with respect to a given carbonate mineral. In waters unsaturated with respect to calcite, Mg+2 generally increased the solubility of calcite. The presence of Mg+2 decreased the solubility of dolomite in waters which were near saturation with respect to dolomite.

72-73:05B-084
NITRATE REDUCTION IN THE VICINITY OF TILE DRAINS,
Davenport, L. A., Lembke, W. D., and Jones, B. A.
Illinois University, Urbana, Department of Agricultural Engineering.
Illinois Water Resources Center, Urbana Research Report No. 64, March 1973.
107 p, 30 fig, 10 tab, 25 ref, 2 append.

Descriptors: *Denitrification, *Drainage, *Nitrates, Porous media, Temperature, Water pollution control, *Tile drains, Path of pollutants.
Identifiers: *Substrate materials, *Temperature effects, *Methanol.

The fate of nitrates as they travel through a long porous column at a slow rate was observed in this study with temperature and substrate materials variable. During a one month period of flow with pore velocities averaging up to 21 centimeters per day, losses as high as 89 percent were found for a methanol treatment at 24 degree C while for 13 degree C losses were reduced to 46 percent. A sawdust substrate material resulted in very little reduction of nitrate concentrations at 24 degree C and actual increases (presumably from mineralization) at 13 degree C. Since methanol was found to be an effective means of removing nitrate from a slowly moving stream of water at temperatures as low as 13 degree C, it will be used as a standard in future field studies to evaluate less expensive substrate materials.

72-73:05B-085
RATIONALE FOR OPTIMUM NITROGEN FERTILIZATION IN CORN PRODUCTION,
Stanford, G.
United States Department of Agriculture, Agricultural Research Service, Soils Laboratory, Beltsville, Maryland.
Journal of Environmental Quality, Vol. 2, No. 2, p 159-166, April-June, 1973.
5 fig, 1 tab, 27 ref.

Descriptors: *Fertilizers, *Fertilization, Fertility, Nutrient removal, Leaching, Nitrogen, Nitrates, Denitrification, Water pollution sources, Groundwater.

During the past decade, the percentage of the corn acreage in the USA receiving N fertilizer has risen steadily. By 1971, in the Corn Belt and five adjoining states, this proportion ranged from 93 to 100% of the total corn acreage. Between 1964 and 1970 the average rate of N applied to fertilized acres increased about 83% in the Corn Belt and 128% in adjacent states (Nebraska, Kansas, Michigan, Wisconsin, and Minnesota). Undoubtedly, there has been an accompanying increase in the proportion of the corn acreage receiving optimum to excessive amounts of N fertilizer. These trends emphasize the importance of developing improved procedures for achieving optimum fertilizer N use (i.e., adequate but not excessive rates, and proper timing for greater efficiency) consistent with the goal of minimizing the possibility of environmental pollution.

72-73:05B-086
WASTE ACCUMULATION ON A SELECTED DAIRY CORRAL AND ITS EFFECT ON THE NITRATE AND SALT OF THE UNDERLYING SOIL STRATA,
Chang, A. C., Adriano, D. C., and Pratt, P. F.
California University, Department of Soil Science and Agricultural Engineering, Riverside.
Journal of Environmental Quality, Vol. 2, No. 2, p 233-237, April-June, 1973. 5 fig, 3 tab, 9 ref.

Descriptors: *Water Pollution Sources, *Animal wastes (wildlife), *Leaching, Nutrient removal, Dairy industry, Nitrogen, Nitrates.

A corral was selected from a typical Chino-Corona, California area dairy to study waste accumulation and distribution on corral surfaces and to determine its effect on underlying soil strata. Waste deposited on the surface tended to accumulate in a small area of the corral; as much as 57% of the waste was in an area equaling 30% of the total corral surface. Considerable decomposition of organic matter and nitrogen loss took place during accumulation; however, collected waste samples were relatively unstable and subject to further decomposition. After a long period of dairy operations, leaching of nitrates, chlorides, and organic matter into soils was substantial. The same order of magnitude of leaching of chloride and organic carbon occurred throughout the entire corral surface. The amount of nitrate underneath the area of heavy waste accumulation was less than that in the other part of the corral. Future improvement in dairy waste management should take this into consideration in order to minimize its potential cause of ground water pollution.

72-73:05B-087
NUTRIENT BALANCES FOR THE EVALUATION OF NUTRIENT SOURCES IN WATER QUALITY MANAGEMENT,
Peters, R. H.
Department of the Environment, Water Quality Branch, Ottawa, Canada.
Water Resources Bulletin, Vol. 9, No. 1, p 49-53, February, 1973. 2 fig, 3 tab, 1 ref.

Descriptors: *Water pollution, *Water quality, *Water quality control, Nutrients, Riverflow, River systems, Leaching.

The methodology for a nutrient balance to evaluate the sources and distribution of nutrients in a small river basin is described. Loadings for total nitrogen and phosphorus are calculated from measured nutrient concentration and river discharge data. Using a special retrieval program and a data storage and processing system, loadings are accumulated over a given time period to allow for time of passage through the basin and seasonal changes in nutrient distribution. Nutrient balances are made with the accumulated loadings to obtain the relative contribution of each nutrient source and the retention of nutrients within the basin through sedimentation and aquatic growth. The methodology has been used to study nutrients in the Qu'Appelle River Basin, Saskatchewan, Canada.

72-73:05B-088
RETURN IRRIGATION WATER IN HAWAII,
Young, R. H. F., and Lao, C.
Hawaii University, Water Resources Research Center, Honolulu.
Water Resources Bulletin, Vol. 9, No. 3, p 538-555, June, 1973. 12 fig, 1 tab, 10 ref.

Descriptors: *Water pollution sources, *Nutrient removal, *Fertilizers, Nitrates, Nitrogen, Groundwater, Hawaii, Sulfates, Domestic water.

Interest in irrigation return water in the Hawaiian Islands has had stimulus from problems in water quality control by the city and county of Honolulu. Water quality changes in the basal lens overlain by sugarcane was monitored. This water is used for domestic supply. The presence of irrigation return water in the basal lenses was evident. Fertilizer components leach into the lenses from agricultural fields. Since this water is used for drinking purposes further studies should be conducted.

72-73:05B-089
AN ECONOMIC ANALYSIS OF SELECTED AGRICULTURAL USES OF WARM WATER IN THE PACIFIC NORTHWEST RESULTING FROM ELECTRIC POWER GENERATION,
Johns, R. W., Folwell, R. J., Dailey, R. R., and Wirth, M. E.
Washington State University, Department of Agricultural Economics, Pullman.
Journal of Environmental Quality, Vol. 2, No. 2, p 224-228, April-June, 1973. 1 fig, 4 tab, 16 ref.

Descriptors: *Water pollution sources, *Thermal pollution, *Thermal power plants, *Aquiculture, Greenhouses, Heating, Catfishes, Carp.

Several possibilities are discussed for making use of waste water: aquaculture, soil heating, and greenhouse heating. Two alternatives were considered for using cooling reservoirs (i) the production of carp for feed or fish meal, and (ii) catfish for the fresh market. Soil warming and greenhouse heating would involve locational problems relative to plant production, processing facilities, and transportation. None of the uses studied showed clear-cut advantages in terms of profits which would attract economic investment. Relocating greenhouses in order to use warm water for heating appears to be a marginal investment. The size of soil-warming systems is limited by the high initial investment, estimated yield response, and vegetable prices.

72-73:05B-090
SUBSURFACE QUALITY TRANSFORMATIONS DURING THE INITIATION OF A NEW STABILIZATION LAGOON,

Wilson, L. G., Clark, W. I., III, and Small, G. G.
Arizona University, Tucson.
Water Resources Bulletin, Vol. 9, No. 2, p 243-257, April, 1973. 3 fig, 3 tab, 15 ref.
(See 72-73:05D-010)

72-73:05B-091
QUALITY OF DRAINAGE WATER FROM A HEAVY-TEXTURED SOIL,
Schwab, G. O., McLean, E. O., Waldron, A. C., White, R. K., and Michener, D. W.
Ohio State University, Agricultural Engineering Department, Columbus.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 6, p 1104-1107, November-December, 1973. 2 fig, 3 tab, 11 ref.

Descriptors: *Water pollution sources, *Runoff, *Leaching, Nutrient removal, Agricultural chemicals, Erosion, Nitrogen, Phosphorus, Drainage.

Sediment, dissolved solids, nine chemical elements or ions, five pesticides, electrical conductivity, pH, and BOD in tile drainage effluent and in surface runoff were measured from one-half acre plots on Toledo silty clay soil near Sandusky, Ohio, for a 3-year period, 1969-1971. Measurements were taken from both conventional tilled and no-tilled plots in continuous corn. Irrigation water was applied each year to simulate heavy rainfall. Recommended fertilizer amounts were applied, but pesticide kinds and amounts were greater than normally required for insect or weed control. Rainfall was above average in 1969 and 1970, and below average in 1971. Sediment losses from the tile and surface drainage water were several times greater for conventional tillage than for no tillage.

72-73:05B-092
INFILTRATION AND LANDFILL BEHAVIOR,
Rovers, F. A., and Farquhar, G. J.
Waterloo University, Waterloo, Ontario, Canada.
Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 99, No. EE5, p 671-690, October, 1973. 7 fig, 8 tab, 33 ref.

Descriptors: *Environmental engineering, *Landfills, Sanitary engineering, Infiltration, Leaching, Absorption, Evaporation, Gases, Methane, Temperature, Thawing.

The effects of infiltration on sanitary landfill leachate and gas production were examined under both field and laboratory conditions. Maximum field leachate production occurred during spring thaw. Production was greatly reduced during the summer. Moisture adsorption prior to leachate flow ranged from 10.0 cm/m to 14.2 cm/m of compacted refuse. The leachate produced was strong. As an indication, concentrations of COD, calcium, chloride and ammonia nitrogen exceeded 40,000 mg/l, 2,500 mg/l, 1,200 mg/l, and 600 mg/l, respectively. Decomposition proceeded anaerobically with the production of methane and carbon dioxide. Periods of rapid moisture influx were accompanied by increased leachate strength, reduced pH, and decreased methane production thus allowing the accumulation of organic acids and subsequent reductions in pH. The interference appeared to have arisen from an increase in oxidation-reduction potential.

72-73:05B-093

LEACHATE TREATMENT BY COAGULATION AND PRECIPITATION,

Thornton, R. J., and Blanc, F. C.
Camp, Dresser, and McKee Incorporated, Boston, Massachusetts.
Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 99, No. EE4, p 535-544, August, 1973. 2 fig, 5 tab, 9 ref.

Descriptors: *Land fills, *Sanitary engineering, *Leaching, Water quality, Chemical precipitation, Environmental engineering, Coagulation, Solid wastes.

When sanitary landiflls are constructed with provisions for collection and treatment of leachates, chemical treatment may be one of the treatment processes employed. The research was conducted to determine the ability of chemical treatment to remove suspended solids, biochemical oxygen demand, chemical oxygen demand, iron, calcium, and magnesium from leachate. Chemical treatment studies were conducted in the laboratory using alum, lime, and ferric chloride. Preliminary results indicate that lime precipitation was most effective. Additional studies revealed that suspended solids, color, and some multivalent cations can be effectively removed from raw leachate using lime. However, significant removals of soluble biochemical oxygen demand were not observed and extremely high lime concentrations in the 300 mg/l 600 mg/l range were required to obtain a relatively clear supernatant resulting in relatively large amounts of sludge.

72-73:05B-094

HERBICIDE CONTAMINATION OF SURFACE RUNOFF WATERS,

Evans, J. O., and Duseja, D. R.
Utah State University, Logan, Department of Plant Science.
Environmental Protection Agency, Technology Series Report, EPA-R2-73-266, June 1973. 99 p. 14 fig, 22 tab, 62 ref.

Descriptors: *Herbicides, *Weed control, Water pollution sources, Persistence, Urea pesticides, Triazine pesticides, 2 4-D, 2,4,5-T, *Return flow, Path of pollutants, Water quality control.
Identifiers: *Herbicide runoff, *Picloram adsorption, Picloram leaching, Herbicide residues, Herbicide adsorption, Canal bank weed control, Diuron, Picloram.

Field and laboratory studies of the movement of herbicides were conducted to determine their potential as contaminants in irrigation return flow. Special emphasis was given to the use of herbicides for vegetation control along ditches, canals and watersheds where high dosages are required to control the excessive growth of grasses and broadleaved weeds. The following herbicides have been studied: substituted urea (diuron), triazines (summitol and atrazine), phenoxyacetic acid (2,4-D and 2,4,5-T) and a substituted pyridine (picloram). The greatest tendency for transport of herbicides in water coming in contact with soils occurs during the initial storms following spray application. If the intensity of the initial precipitation is not sufficient to cause movement across the soil, the danger of herbicide movement is essentially eliminated. The highest concentrations (ppm) of herbicide observed in surface waters were 1.8, 0.5, 4.2, 1.2 and 2.7 for diuron, summitol, 2,4-D, 2,4,5-T and picloram, respectively. These levels were observed immediately below treated areas receiving the higher recommended dosages of the herbicides. All herbicide concentrations dropped below the limit of detection within a few hundred meters below the sprayed areas. Presumably, soil filtration, adsorption and dilution are primarily responsible for the loss of herbicides from water.

72-73:05B-095

SIGNIFICANCE OF MAN-MADE SOURCES OF PHOSPHORUS: FERTILIZERS AND FARMING,

Cooke, G. W., and Williams, R. J. B.
Rothamsted Experimental Station, Harpenden (England).
Water Research, Vol. 7, Nos. 1/2, p 19-33, January-February 1973. 9 tab, 26 ref.

Descriptors: *Phosphates, Water pollution sources, *Agricultural runoff, Fertilizers, Livestock, Erosion, Leaching, Animal wastes (Wildlife), Path of pollutants, Nutrients, Water pollution control, Runoff, *Farm wastes, Cattle, Hogs, Sheep, *Phosphorus, *Poultry.
Identifiers: England.

There are three ways which phosphorus from agricultural areas can enter natural water supplies: in drainage water; in eroded soil; or from animal excreta. Study of these sources showed that in most cases runoff from agricultural lands contained less P than the receiving waters. However, where erosion occurs, P levels in water may be increased since fertilizers tend to fix themselves to topsoil which is lost first. The P in muds is solubilized in anaerobic reducing conditions and becomes available to rooted plants and microorganisms. Most animal excreta is reapplied to land as fertilizer and may occasionally pollute streams if it is improperly applied or if heavy rains occur. In addition, new methods of handling excreta as slurries increase the potential of pollution by over application or leakage of storage tanks. One source of phosphorus in natural waters which is often not considered is wild birds. These may add significantly to P levels in water. At present, it appears that agricultural sources add little P to natural waters. However, steps must be taken to assure that the three potential sources are adequately controlled.

72-73:05B-096

THE ACCELERATION OF THE HYDROGEOCHEMICAL CYCLING OF PHOSPHORUS,

Stumm, W.
Eidgenoessische Anstalt fuer Wasserversorgung, Abwasserreinigung und Gewaesserschutz, Zurich (Switzerland).
Water Research, Vol. 7, Nos. 1/2, p 131-144, January-February, 1973. 9 fig, 2 tab, 27 ref.

Descriptors: *Water pollution sources, *Phosphorus, *Cycling nutrients, Fertilizers, Oxygen demand, Limiting factors, Sediments, Water pollution effects, Phosphates, Nutrients, Water pollution control, Animal wastes, Farm wastes, Detergents, Municipal wastes, Lakes, Agricultural runoff, Oceans, Rivers.
Identifiers: Fate of pollutants, Mobilization, Phosphorites, Phosphorus cycle.

By mining phosphorus in progressively increasing quantities, man disturbs the ecological balance and creates undesirable conditions in inland waters, estuaries and coastal marine waters. The civilizatory increase in phosphorus supply to the oceans although of little consequence to the oxygen reserves of the deep sea, augments markedly the marine environments with intermittent or permanent oxygen deficient conditions. Because most aquatic food resources are produced in estuaries and coastal areas, the deterioration in water quality of these regions decreases the potential harvest of marine animal protein. Present agricultural practice of excessively fertilizing land needs to be reexamined; present agricultural technology must not without modification be exported to tropical areas. Present drainage systems for sewage, industrial wastes and storm water runoff accelerate the transport of nutrients and other pollutants to the rivers and the sea; waste plants are remarkable inefficient in mitigating this civilizatory flux.

72-73:05B-045

WATER-LEACHABLE NUTRIENTS FROM FROZEN OR DRIED PRAIRIE VEGETATION,

White, E. M.

South Dakota State University, Plant Science Department, Brookings.

Journal of Environmental Quality, Vol. 2, No. 1, p 104-107, January-March, 1973. 1 fig, 4 ref.

Descriptors: *Water pollution sources, *Runoff, Nitrogen, Phosphorus, Calcium, Magnesium, Nutrient removal, Leaching, Prairie soils, Vegetation.

Runoff from agricultural lands in South Dakota is mainly from melting snow and spring rains. Nutrient enrichment of this water may be enhanced during the fall and winter by the rupturing of plant cells by freezing. Native prairie vegetation and mulch were sampled in late summer, early fall, and spring to determine the effect freezing, in comparison to drying, would have on nutrient release to water. Release of Ca, Mg, K, P, NO3-N, and NH4-N by freezing was related to stage of growth or decomposition of the vegetation. Freezing increased nutrient release if the vegetation were growing when it was frozen. Soil genesis, ecological relations between plant species, and runoff water quality could be affected by the relative release of different kinds of nutrients.

Section XXIV

WATER QUALITY MANAGEMENT AND PROTECTION

EFFECTS OF POLLUTION (Group 05C)

72-73:05C-001
CARBON CYCLE IN SEDIMENT-WATER SYSTEMS,
Kerr, P.C., Brockway, D.L., Paris, D.F., and Craven, S.E.
National Environmental Research Center, Corvalis, Oregon.
Journal of Environmental Quality, Vol 2, No 1, p 46-52, January-March 1973.
1 fig, 72 ref.

Descriptors: *Reviews, *Carbon cycle, *Aquatic environment, *Sediment-water interfaces, *Aquatic microorganisms, Carbon dioxide, Sinks, Ecosystems, Adsorption, Sediments, Anaerobic bacteria, Aerobic bacteria, Algae, Aquatic productivity, Cycling nutrients, Aerobic conditions, Anaerobic conditions, Biodegradation, Path of pollutants, Secondary productivity, Carbon, Nutrients, Organic matter, Nitrogen, Phosphorus, Sorption, Clay minerals, Fungi, Yeasts, Phosphates, Carbonates, Primary productivity, Hydrogen ion concenctration, Methane, Photosynthesis, Benthos, E. coli, Bioindicators, Degradation (Decomposition), Organic acids, Sedimentation, Metabolism, Bicarbonates, Bottom sediments.
Identifiers: Nutrient interchange, Mineralization, Heterotrophy, Organic carbon, Substrate utilization, Autotrophic nutrition, Heterotrophic nutrition.

Literature relevant to the extent and rate of carbon exchange between sediment and water is reviewed and the general implication of the role of carbon in regulating biological activity is discussed. Several conclusions are drawn from the review. The extent of adsorption of organics to clay minerals in natural aquatic ecosystems is not known. Sorption, desorption, sedimentation, and aerobic and anaerobic activity are affected by physical factors such as depth and mixing. Certain data indicate that organisms cannot utilize organic material sorbed to clay minerals; other data indicate that growth of certain bacteria and yeast is stimulated by the addition of clay minerals. Although the exact substrate (s) is not known, aerobic and anaerobic decomposition of organic materials occurs in and on sediments. Aerobic decomposition seems to result in three different reactions affecting sediment-water carbon exchange: (1) Methane gas is produced and released from sediments. (2) Organic acids produced by anaerobes can serve as carbon sources for aerobes as well as aiding in solubilization of carbonates and affecting sorptive processes. (3) Carbon dioxide produced by anaerobes may be combined in some manner and remain in the sediments. The fact that most deep sediments retain organic carbon indicates that sediments may be sinks for organics. Possible sediments serve as organic carbon sinks simply because the rate of sedimentation exceeds the rate of decomposition.

72-73:05C-002
THE NITROGEN CYCLE IN SEDIMENT-WATER SYSTEMS,
Keeney, D.R.
Wisconsin University, Madison, Department of Soil Science.
Journal of Environmental Quality, Vol 2, No 1, p 15-29, January-March 1973.
6 fig, 6 tab, 199 ref.

Descriptors: *Reviews, *Aquatic productivity, *Sediment-water interfaces, *Nitrogen cycle, Eutrophication, Environmental effects, Cycling nutrient, Nitrification, Dentrification, Nitrogen fixation, Water quality, Ecosystems, Algae, Bacteria, Biomass, Nitrogen, Sediments, Water temperature, Cyanophyta, Anabaena, Aquatic soils, Mineralogy, Soil properties, Lake morphology, Hydrogen ion concentration, Dissolved oxygen, Oxidation-reduction potential, Nutrients, Lakes, Electrodes, Respiration, Bacteria, Plankton, Incubation, Pseudomonas.
Identifiers: Mineralization, Immobilization, Ammonification, Nutrient interchange, Fate of pollutants, Anerobic respiration, N-15 Lake Mendota, Bantam Lake, Green Lake, Lake Kinneret, Nitrobacter, Bacillus, Achromobacter, Micrococus, Nitrosomonas europea, Clostridium pasteurinanum.

The available literature on the fate of nitrogen in waters and sediments is reviewed. Emphasis is placed on the importance of N to aquatic productivity, the pathways leading to N gains or losses in aquatic ecosystems, and the availability of N in sediments to the overlying waters. Important biological reactions include N mineralization and immobilization, nitrification and denitrification, and N fixation. The effect of sediment properties, lake morphology and environmental factors (pH, temperature, dissolved oxygen, oxidation-reduction) on the pathways and rates of N turnover are considered. The mixing process in sediments appear to be the most important in releasing sediment-N to waters. Several facets of the N cycle in waters and sediments require further elucidation. Research needs are outlined.

72-73:05C-003
MICROBIOLOGICAL QUALITY OF SURFACE DRAINAGE WATER FROM THREE SMALL IRRIGATED WATERSHEDS IN SOUTHERN IDAHO,
Smith, J.H. and Douglas, C.L.
Agricultural Research Service, Kimberly, Idaho. Snake River Conservation Research Center.
Journal of Environmental Quality, Vol 2, No 1, p 110-112, January-March 1973. 2 tab, 8 ref.

Descriptors: *Water quality, *Irrigation effects, *Coliforms, *Enteric bacteria, Water analysis, Water pollution effects, Irrigation water, Water pollution, Streptococcus, Pathogenic bacteria, Filtration, Separation techniques, Pollutant identification, Surface runoff, Idaho, Dissolved oxygen, Biochemical oxygen demand, Water temperature.
Identifiers: *Fecal streptococci, *Fecal coliforms, Most probable number test, Standard methods.

Irrigation water applied to and leaving three small watersheds in southern Idaho was analyzed to determine the influence of surface irrigation on bacteriological quality of surface runoff water. The sites were inhabited by families raising various crops and some livestock. Presumptive, confirmed and completed coliform counts were made according to Standard Methods, MPN's were calculated, fecal coliform counts were made by MPN analyses, and fecal streptococci were determined by micropore filtrations. DO, BOD, and water temperatures were also determined. The irrigation water samples were polluted with microorganisms associated with human and animal wastes, as indicated by numbers of coliforms and by fecal coliform/fecal streptococci ratios. There was a trend toward increasing numbers of coliforms and fecal coliforms in the drainage water compared to the irrigation water, but the differences were generally within the confidence limits for MPN analyses. On two of the three watersheds, microorganisms incubated on plating agar at 20C had higher counts in the drainage than in the irrigation water. Fecal streptococci numbers were significantly higher in the drainage than in the irrigation water on two of the three small watersheds. Even though microorganisms counts tend to be higher in drainage than in the irrigation water on these three small watersheds, irrigation use has a minimal deleterious effect on the microbiology of these waters.

72-73:05C-004
NITROGEN, PHOSPHORUS AND OTHER INORGANIC MATERIALS IN WATERS IN A GRAVITY-IRRIGATED AREA,
Fitzsimmons, D.W., Lewis, G.C., Naylor, D.V.
Idaho University, Moscow. Department of Agricultural Engineering; and Idaho University, Moscow. Department of Soils.
Transactions of the American Society of Agricultural Engineering, Vol 15, No 2, P 292-295, 1972. 5 fig, 5 tab, 12 ref.

The kinds and amounts of inorganic materials were determined in surface and groundwaters in an intensively-farmed gravity-irrigated area (Boise Valley, Idaho). Water samples, taken throughout the crop growing season were analyzed for nitrate-nitrogen, ammonia, and organic nitrogen, two forms of phosphorus, and total solids. Water samples were collected at 2-week intervals throughout the 1970 season from 79 sites which included 29 farms in four irrigation districts. The mean concentrations of all three forms of nitrogen were found to be relatively low. The mean concentration of each nitrogen form was greater in the surface runoff than in the headwater; the groundwater contained more nitrate-nitrogen than the other water sources, possibly an indication that nitrate is being leached from the soil by percolating irrigation water; this material could also come from feedlots, dairies and septic tank drain fields in the area. The surface runoff also contained the largest concentrations of total phosphorus and total solids. The groundwater was found to contain a relatively large concentration of both ortho and total phosphorus.

72-73:05C-005
ON THE NECESSARY AND SUFFICIENT FOR A LONG-TERM IRRIGATED AGRICULTURE,
Moore, C.V.
United States Department of Agriculture, Davis, California.
Water Resources Bulletin, Vol 8, No 4, p 802-812, August, 1972. 3 fig, 12 ref.
(See 72-73:05B-032)

72-73:05C-006
SALINITY-OZONE INTERACTIONS ON PINTO BEANS: INTEGRATED RESPONSE TO OZONE CONCENTRATION AND DURATION,
Maas, E.V., Hoffman, G.J., Rawlins, S.L., and Ogata, G.
United States Department of Agriculture, Riverside, California.
Journal of Environmental Quality, Vol 2, No 3, p 400-404, July-September, 1973. 2 fig, 2 tab, 13 ref.
(See 72-73:03C-005)

72-73:05C-007
INTERACTIVE EFFECTS OF SALINITY AND OZONE ON GROWTH AND YIELD OF GARDEN BEET,
Ogata, G. and Maas, E.V.
United States Department of Agriculture, Riverside, California.
Journal of Environmental Quality, Vol 2, No 4, p 518-520, October-December, 1973. 2 tab, 12 ref.
(See 72-73:03C-006)

72-73:05C-008
LEACHING REQUIREMENT STUDIES: SENSITIVITY OF ALFALFA TO SALINITY OF IRRIGATION AND DRAINAGE WATERS,
Bernstein, L. and Francois, L.E.
United States Department of Agriculture, Agricultural Research Service, Salinity Laboratory, Riverside, California.
Soil Science Society of America Proceedings, Vol 37, No 6, p 931-943, November-December, 1973. 4 fig, 10 tab, 17 ref.

Descriptors: *Salt balance, *Crop response, Leaching, Alfalfa, Lysimeters, Irrigation practices, Sodium, Drainage engineering.

Alfalfa was grown in 0.6 by 1.5 m greenhouse lysimeters and irrigated with two waters of EC 1 and 2 mmho/cm prepared by adding equivalent amounts of NaCl and CaCl2 to a 0.4 mmho/cm tap water. Yields showed relatively little effect of leaching fraction (LF) within the limits consistent with steady-state salt balance for suction-drained lysimeters but decreased 26% at the lowest Lf for gravity-drained lysimeters. Yields with the 2 mmho/cm irrigation water treatments were consistently about 10% less than those with the 1 mmho/cm water. Cessation of leaching or reduciton of LF to levels requiring drainage water salinities for salt balance at steady state to exceed 35 mmho/cm, the maximum salinity achievable by alfalfa roots, eventually reduced yields. Yields were significantly higher when leaching was done every third or sixth irrigation than in every irrigation while maintaining the same average LF of 1/32 and 1/16 for the 1 and 2 mmho/cm irrigation waters, respectively.

72-73:05C-009
CELL WALL PROPERTIES OF COTTON ROOTS AS INFLUENCED BY CALCIUM AND SALINITY,
Gerard, C.J. and Hinojosa, E.
Texas A&M University, Agricultural Research and Extension Center, Weslaco.
Agronomy Journal, Vol 65, No 4, p 556-560, July-August, 1973. 11 fig, 1 tab, 15 ref.

Descriptors: *Salinity, *Crop response, Calcium, Root development, Cotton, Root system, Root zone.

Research was conducted to determine the influences of salinity and Ca uptake on cell wall properties of cotton roots. It was postulated that examination of cell wass properties might give insight on the role of Ca in moderating the influences of salinity and toxic ions on cellular stability and plant growth. Age and Ca are exxential to the development of thick cell walls in the stele. Thick cell walls exhibit high birefringence under polarized light. Salinity reduced Ca uptake and concentration of cotton roots. Xylem and phloem cell walls of cotton roots grown in solutions with sufficient Ca and low salinity thickened and in about 70 hours, exhibited high birefringence. Young cell walls in the pericycle or laterals did not exhibit birefringence. Even at adequate level of Ca, salinity retarded the development of thick cell walls and high birefringence in the stele to about 140 hours.

72-73:05C-010
ENVIRONMENTAL INDICATORS FOR PESTICIDES,
Strickland, J. and Blue, T.
Stanford Research Institution, Menlo Park, California
Avaliable from the National Technical Information Service as PB-210, 666, Prepared for Council on Environmental Quality, April 1972. 123 p, 8 fig, 15 tab. SRI Project No. ECU-1608 Contract No. EQC217.

Descriptors: *Pesticide residues, *Water pollution effects, *Monitoring, *Transportation, *Path of pollutants, *Lakes, *Rivers, *Estuaries, Fish, Public health, Wildlife, Rain, Water pollution sources, Pesticides, Insecticides, Herbicides, Fungicides, Industrial production, Storage, Air, Water pollution, Soils, Foods, Food chains, Chlorinated hydrocarbon pesticides, Mercury, Metals, Heavy metals, Phenols, Copper, Copper sulfate, 2,4,5-T, 2,4-D Precipitation (Atmospheric),Aldrin, DDT, Dieldrin, Endrin, Heptachlor, Carbamate pesticides, Organophosphorus pesticides, Runoff, Ponds, Swamps, Streams, Oceans, Absorption, Fishkill, Toxicity, Phosphothioate pesticides.
Identifiers: Pentachlorophenol, Parathion, Chloredane, Heptachlor epoxide, Lindane, Methoxychlor, Toxaphene.

Results are presented from a study concerned with environmental indicators of pesticides. The indicators include consideration of: (1) Production, imports, exports, and consumption of pesticides by type and overtime, (2) amounts of pesticides found in food, air, water, soil, wildlife, plants, and the human body, and (3) indirect measures of pesticide utilization as they relate to public health, crop quality and yield, and recreational and aesthetic values. Steps are identified which should be taken for future collection and processing of the data necessary for caluclation of these indicators at appropriate intervals. A comprehensive framework was developed which characterizes the modes by which materials move, the mediums affected, the ecological phenomena that can be observed, and the environmental factors concerned. Recommendations are included for effectively orienting and managing pest control programs with maximum environmental enhancement.

72-73:05C-011
SALINITY-OZONE INTERACTIVE EFFECTS ON YIELD AND WATER RELATIONS OF PINTO BEANS,
Hoffman, G.J., Maas, E.V., and Rawlins, S.L.
United States Department of Agriculture, Riverside, California
Journal of Environmental Quality, Vol 2, No 1, p 148-158, January-March, 1973.

4 fig, 2 tab, 16 ref.
(See 72-73:03C-009)

Section XXV

WATER QUALITY MANAGEMENT AND PROTECTION

WASTE TREATMENT PROCESSES (Group 05D)

72-73:05D-001
BEST COMBINATION OF WASTE TREATMENT AND SPATIALLY DISTRIBUTED DISCHARGE OF EFFLUENT,
Mendiratta, A. K., and Davidson, B.
Rutgers - The State University, New Brunswick, New Jersey, Department of Chemical Engineering; and Rutgers - The State University, New Brunswick, New Jersey, Department of Biochemical Engineering.
Water Resources Research, Vol. 8, No. 3, p 565-585, June, 1972. 10 fig, 3 tab, 31 ref.

Descriptors: *Waste water treatment, *Water quality control, *Effluents, *Biochemical oxygen demand, *Dissolved oxygen, Distribution, Standards, River basins, Planning, Optimization, *Mathematical models, Systems analysis, Pipelines, Networks.
Identifiers: *Water quality management, Optimal control theory, Stream quality standard.

The optimal control theory based on Pontryagin's minimum principle has been applied to the problem of specifying the best combination of minimum percent BOD waste treatment and effluent distribution policies for a single plant on a specified polluted river segment. The analysis features a new dual water quality stream standard consisting of a minimum allowable DO concentration at every point in the river segment combined with a maximum allowable BOD concentration at a specified downstream point. The optimal BOD effluent distribution policies are compared with choice suboptimal effluent discharge patterns associated with best single point, best uniform, and best bang-bang injection policies. The inequality constraints, the nonlinearities in the system model, and the synthesis of the optimal controls were handled in a direct manner by using the Pontryagin control theory principle combined with gradient search and penalty function techniques. The results establish certain guidelines for increasing the assimilative capacity of a given river segment through judicious combinations of minimum percent BOD waste treatment and continuous BOD effluent distribution or dumping patterns associated with single plant effluents. Certain cost factors associated with the pipeline distributer network and treatment plant could be incorporated directly into the optimization algorithm.

72-73:05D-002
DELINEATION OF AREAS FOR TERRESTRIAL DISPOSAL OF WASTE WATER,
Bond, J. G., Williams, R. E., and Shadid, O.
Idaho Bureau of Mines and Geology, Moscow.
Water Resources Research, Vol. 8, No. 6, p 1560-1573, December, 1972. 9 fig, 11 ref.

Descriptors: *Waste water treatment, *Sprinkler irrigation, Groundwater, Groundwater movement, Water table aquifers, Shallow water, Idaho, Irrigation, Basalts, Fertilization, Water quality, Hydrogeology, Hydrologic aspects, Hydrologic systems, *Water reuse, *Waste water disposal.
Identifiers: Renovation (Wastewater), Snake River Basin.

Renovation of waste-water, particularly with respect to organic and nutrient constituents, through irrigation with coincidental crop fertilization and groundwater recharge is proposed for hydrogeologically suitable portions of the Snake River plain, instead of expensive tertiary or sometimes secondary treatment. The region near Idaho Falls and Blackfoot has been used as a case study area to establish the methodology for selecting the most suitable terrestrial disposal sites. Safeguarding surface water and groundwater resources, providing for maximum probability of proper renovation of waste water, and minimizing design and supervision requirements are conditions that must be satisfied by any terrestrial waste water disposal project. The criteria for selecting sites that meet these conditions for proper disposal and renovation include gently sloping topography, a thick subsurface section of unconsolidated, unsaturated porous medium, a surficial mantle of high sand-silt content, and a well-understood shallow groundwater flow system. When evaluation and mapping apply to these criteria in the area around Idaho Falls and Blackfoot, the delineation of sections of land where successful terrestrial disposal of waste water can be expected is facilitated.

72-73:05D-003
METHODS FOR APPORTIONING COSTS AMONG PARTICIPANTS IN REGIONAL SYSTEMS,
Giglio, R. J., and Wrightington, R.
Massachusetts University, Amherst, Department of Industrial Engineering.
Water Resources Research, Vol. 8, No. 5, p 1133-1144, October, 1972. 17 ref.

Descriptors: *Cost sharing, *Waste water treatment, *Water pollution, *Treatment facilities, *Linear programming, Separable costs, Benefits, Regional analysis, Mathematical models, Systems analysis, Optimization.
Identifiers: Gaming-theory, Bargaining methods, Economic analysis.

Five methods for apportioning the costs of joint or regional waste water treatment facilities among users are discussed. It is assumed that polluters will clean their wastes and pay directly at least a fraction of the costs of treating their wastes. The methods examined are: (1) Cost sharing based on the measure of pollution; (2) cost sharing based on single plant costs with a rebate proportional to the measure of pollution; and (3) cost sharing based on the separable costs remaining benefit method; the two additional methods rely on game-theory; (4) cost sharing based on free market bargaining; and (5) cost sharing based on bargaining including the regional authority as a participant, using linear programming. Using numerical and theoretical arguments it is demonstrated that often methods 1-3 do not provide an apportionment that satisfies all people involved and that a potential participant may find it economically advantageous not to join the regional plan, possibly forcing the adoption of a more costly system. These difficulties will frequently arise when any plan is subjected to the pressures of free market bargaining. Methods 4-5 are introduced to deal with this problem. The bargaining methods prove that some cost-sharing problems have no unique solutions and that others have no viable solution at all unless the regional authority can obtain a subsidy.

72-73:05D-004
DEEP PLOWING - AN ENGINEERING APPRAISAL,
James, P. E., and Wilkins, D. E.
United States Department of Agriculture, Beltsville, Maryland.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 420-422, May-June, 1972. 5 fig, 4 tab, 4 ref.
(See 72-73:08C-001)

72-73:05D-005
EVALUATION OF CURRENT TECHNIQUES FOR NUTRIENT REMOVAL FROM WASTEWATERS,
Shindala, A.
Mississippi State University, Department of Civil Engineering.
Water Resources Bulletin, Vol. 8, No. 5, p 987-998, October, 1972. 32 ref.

Descriptors: *Waste treatment, *Saline water, *Drainage water, *Nutrient removal, Nitrogen compounds, Phosphorus compounds, Denitrification, Water treatment, Water quality control, Water pollution treatment, Eutrophication.

A comprehensive evaluation of current techniques for removal of nitrogen and phosphorus was conducted. Extensive searchings of the literature demonstrated that the technology is available to provide effective nutrient removal at a reasonable cost. Current methods for phosphorus removal include biological, chemical precipitation, and ion exchange. Nitrogen removal processes include biological denitrification, ammonia stripping, and ion exchange. This paper consists of a brief summary of the work. A copy of the complete work is available from the author.

72-73:05D-006
ABSORPTION OF MERCURIC CATION BY TANNINS IN AGRICULTURAL RESIDUES,
Waiss, A. C., Jr., Wiley, M. E., Kuhnle, J. A., Potter, A. L., and McCready, R. M.
United States Department of Agriculture, Agricultural Research Service, Western Regional Research Laboratory, Berkeley, California.
Journal of Environmental Quality, Vol. 2, No. 3, p 369-371, July-September, 1973. 5 tab, 15 ref.

Descriptors: *Water pollution treatment, *Cation adsorption, Heavy metals, Mercury, Chelation, Oxidation, Reduction.

Two common environmental pollutants are agricultural residues and waste streams of water containing only traces of heavy metals (such as mercury at 10 or more ppb) from mining or manufacturing operations. Agricultural residues contain tannins, polyphenolic substances, pectin, and other polymers - all with chemically reactive groups that can chelate, reduce, oxidize, demonstrate ion exchange properties, and aid in removing traces of heavy metals from dilute waste water streams at low cost. Finely ground and water-washed agricultural residues were slurried in water and packed into columns for absorption tests with heavy metals. Solutions of known concentrations of heavy metals were passed through the packed columns which were then eluted with water or with alkaline or acidic solutions. The fractions and the column absorbents were then analyzed by standard atomic absorption methods. The nature of the physical and chemical forces that are effective in metal absorption from agricultural residues is not clear.

72-73:05D-007
EFFECTS OF SURFACE IRRIGATION WITH DAIRY MANURE SLURRIES ON THE QUALITY OF GROUNDWATER AND SURFACE RUNOFF,
Barker, J. C., and Sewell, J. I.
Tennessee University, Agricultural Engineering Department, Knoxville.
Transactions of the American Society of Agricultural Engineers, Vol. 16, No. 4, p 804-807, July-August, 1973. 1 fig, 4 tab, 9 ref.

Descriptors: *Water pollution sources, *Agricultural runoff, Feedlot, Dairy industry, Waste treatment, Waste disposal, Runoff, Groundwater, Water quality.

An experimental manure slurry irrigation system was established at the University of Tennessee Knoxville Cherokee Dairy Farm to study this waste management problem. This system requires land on which to irrigate with the slurry. The quantities of manure and wastewater which pastures and cropland can receive without polluting groundwater, surface water, and the land itself have generally not been established. The major objectives were to determine the effects of slurry irrigation on surface runoff and groundwater quality and to develop techniques for irrigating with dairy manure slurry. A 4-acre plot with ground slopes varying from about 20 percent to almost flat was selected as a manure slurry saturation area to study the effects of the surface spreading of this slurry on the quality of groundwater and surface runoff. Three groundwater wells extending approximately 50 feet below the ground surface were drilled in the vicinity of the saturation area.

72-73:05D-008
OPTIMAL CONTROL OF NITROGEN LOSSES FROM LAND DISPOSAL AREAS,
Haith, D. A.
Cornell University, Agricultural Engineering Department, Ithaca, New York.
Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 99, No. EE6, p 923-937, December, 1973. 4 fig, 6 tab, 28 ref.

Descriptors: *Sewage treatment, *Sewage disposal, *Water pollution sources, Nitrogen, Leaching, Runoff, Sewage effluents, Waste water disposal, Soil filters.

The land disposal alternative is not free from water pollution potential. Nitrogen losses from percolation and runoff may contaminate water supplies and contribute to the eutrophication of aquatic systems. A general model of the soil nitrogen budget has been developed for the purpose of comparing alternative strategies for controlling nitrogen leaching losses from a cropped land disposal area. The model is based on monthly inventory equations for both inorganic and organic soil nitrogen and includes the processes of plant nitrogen uptake, mineralization of organic nitrogen, and leaching. The model was tested using nitrogen budget data from several New York corn production field studies. The model was linearized and linear programming was used to find monthly disposal schedules that maximize annual returns from a sewage sludge disposal system subject to constraints on nitrogen leaching losses.

72-73:05D-009
PROCESS KINETICS FOR DENITRIFICATION,
Johnson, W. K.
Minnesota University, Department of Civil and Mineral Engineering, Minneapolis.
Journal of the Sanitary Engineering Division, American Society of Civil Engineers, Vol. 98, No. SA4, p 623-6 4, August, 1972. 3 fig, 1 tab, 29 ref.

Descriptors: *Sewage treatment, *Activated sludge, *Denitrification, Carbon filters, Environmental sanitation, Sanitary engineering, Sewage bacteria, Water quality, Water pollution sources.

Kinetic equations for biological growth, substrate utilization, and oxygen uptake with the activated sludge process may be modified and used to describe a denitrification process. A basic difference between the processes is that the dependency of variables is interchanged. For denitrification the oxygen equivalent from the nitrates is the independent variable and the substrate supplied is a dependent variable. Coefficients used in the kinetic equations for denitrification are not well defined as yet but will differ from activated sludge particularly due to the lower yield characteristics of the denitrification process. Experimental data support the validity of the equations as presented. The rate of nitrate reduction is shown to be a linear function of the sludge loading rate, and the ratio of substrate applied to nitrate reduced BOD/N was found to be essentially constant over a wide range of sludge loadings. The exact magnitude of the BOD/N ratio is a function of the yield characteristics of the substrate and the yield characteristics of the biological treatment system employed. When the substrate or carbon source must be purchased process yields are particularly important.

72-73:05D-010
SUBSURFACE QUALITY TRANSFORMATIONS DURING THE INITIATION OF A NEW STABILIZATION LAGOON,
Wilson, L. G., Clark, W. I., III, and Small G. G.
Arizona University, Water Resources Research Center, Tucson.
Water Resources Bulletin, Vol. 9, No. 2, p 243-257, April, 1973. 3 fig, 3 tab, 15 ref.

Descriptors: *Sewage treatment, *Sewage lagoons, *Seepage, Deep percolation, Nitrification, Denitrification, Water pollution sources, Leaching, Nitrates, Chemical oxygen demand, Groundwater.

Raw sewage was metered into a newly-constructed lagoon of the Pima County Department of Sanitation, Tucson, Arizona. Seepage losses were calculated from data on inflow, evaporation and change in storage. Water samples were obtained from shallow suction cups, a 40 foot and a 60 foot PVC well and a 100 foot access tube, all located inside the lagoon. Samples from these wells, together with water samples from the lagoon, were examined for coliform organisms and various physical and chemical constituents. Of special concern were transformations in nitrogen. Estimated seepage rates in the lagoon during inundation ranged from 0.20 feet per day to 0.10 feet per day. Water level observations in wells reflected the percolation of effluent to the water table, 70 feet below land surface. Initially, the nitrate ion levels in the suction cup samples were high, manifesting the leaching of indigenous soil nitrogen. With the onset of anaerobic conditions at the base of the lagoon, nitrification was inhibited at the soil surface and ammonia became the predominant form of nitrogen in the soil solution. Sorption of ammonium ion appeared to occur on clay particles in a soil zone of high cation exchange capacity. There were no undesirable microbial or chemical effects of recharge from lagoon seepage on native groundwater quality.

72-73:05D-011
HEAD DROP ACROSS BAR SCREENS,
Yao, K. M.
World Health Organization, West Pakistan.
Journal of the Water Pollution Control Federation, Vol. 44, No. 7, p 1448-1452, July, 1972. 4 fig, 3 ref.

Descriptors: *Sewage treatment, *Treatment facilities, Screens, Head loss, Hydraulics.

The head drop across screens used in sewage treatment plants is discussed. Various equations are presented along with their limitations. Appropriate times to use each equation are listed. A nomograph for use by plant operators is also developed.

72-73:05D-012
NITROGEN REMOVAL BY SOIL MECHANISMS,
Lance, J. C.
United States Water Conservation Laboratory, Phoenix, Arizona.
Journal Water Pollution Control Federation, Vol. 44, No. 7, p 1352-1361, July, 1972. 3 fig, 32 ref.

Descriptors: *Nutrient removal, *Nitrogen, Leaching, Denitrification, Sewage treatment, Solid wastes.

Nitrogen may be removed from a soil system in gaseous form by volatilization of ammonia or by denitrification. The amount of ammonia volatilized in a land disposal system is small, but large amounts of nitrogen could be removed during travel through a long stream or channel to the disposal area. Denitrification is perhaps the most desirable removal process because large amounts of nitrogen can be removed and transferred to the atmosphere as nitrogen gas. The nitrogen is thus completely removed from the system without causing air pollution. Additional research will be needed to determine whether denitrification can be sustained in a groundwater recharge system without prior oxidation of ammonium and/or additional sources of carbon.

72-73:05D-013
HAZARDS ASSOCIATED WITH THE USE OF CHLORINATED OXIDATION POND EFFLUENTS FOR IRRIGATION,
Kott, Y.
Technion - Israel Institute of Technology, Haifa.
Water Research, Vol. 7, p 853-862, 1973. 7 tab, 17 ref.

Descriptors: *Chlorination, Effluents, Hazards, *Irrigation water, *Oxidation lagoons, Water quality control, *Water reuse, Water treatment, *Waste water treatment.
Identifiers: *Israel.

In Israel more than 200 oxidation ponds are in use, most of them serving rural communities. It is natural to assume, therefore, that in a country where about 90 percent of the water resources are utilized, most of the oxidation pond effluents will be used for irrigation. Reuse of wastewater for agricultural purposes is dependent on health hazards being overcome. Investigations using 8 miligrams per litre chlorine applied to oxidation pond effluents caused no algal kill within the first 2 hours of contact. Available chlorine attacks bacteria, causing coliform count to drop from 100,000 per 100 ml to a few tens. Enterovirus counts dropped from about 80 per 100 ml to 37 per 100 ml after chlorination. Vibro cholerai (El-Tor) were killed under these conditions, and MPN dropped from 1000 per 100 ml in the influent wastes to 2 per 100 ml in the effluents. A 5 mg per l dose of chlorine at 1 h contact time killed these sensitive bacteria, decreasing MPN to less than 2 per 100 ml. Differences between the efficiency of chlorination experiments under laboratory and field conditions would necessitate the application of 15 mg per l chlorine for 2 h of contact. Further study is needed before unrestricted use of oxidation pond effluents for irrigation purposes is safe unless strict regulations are issued.

72-73:05D-014
NITROGEN REMOVAL: A LITERATURE REVIEW,
Reeves, T. G.
Kansas State Board of Health, Topeka, Division of Environmental Health.
Journal Water Pollution Control Federation, Vol. 44, No. 10, p 1895-1908,
October 1972. 99 ref.

Descriptors: *Nitrogen, *Nitrogen compounds, *Water pollution treatment, *Water pollution sources, *Reviews, *Waste water treatment, *Nutrient removal, Fertilizers, Methodology, Microbial degradation, Chemical precipitation, Biological treatment, Nitrification, Denitrification, Filtration, Distillation, Ion exchange, Chlorination, Reverse osmosis, Nitrogen fixing bacteria, Activated carbon, Activated sludge, Electrochemistry, Pseudomonas, Waste water (Pollution).
Identifiers: Chemical treatment, Air stripping, Nitrosomonas, Nitrosococcus, Nitrosospura, Nitrosocystis, Nitrosogloes, Achromobacter, Bacillus, Micrococcus.

A literature review is presented on sources of and techniques for the removal of nitrogen and nitrogen compounds from wastewater. While sources may vary as widely as domestic wastes to fertilizer, treatment is limited by practicality and expense. Large scale air stripping cannot yet be considered practical due to cost and physicochemical problems. Ion exchange may be feasible but only on a small scale. The most practical available method is biological nitrification-denitrification involving a 3-stage system which includes a BOD removal unit, a nitrification (aerobic) unit, and a denitrification (anaerobic) unit. Other processes, such as electrochemical precipitation, electrodialysis, reverse osmosis, distillation, breakpoint chlorination, filtering, and slude techniques are discussed.

Section XXVI

WATER QUALITY MANAGEMENT AND PROTECTION

ULTIMATE DISPOSAL OF WASTES (Group 05E)

72-73:05E-001
SOIL STORAGE LIMITATIONS ON EFFLUENT IRRIGATION,
Settergren, C. D.
Missouri University, Department of Forestry, Columbia.
Water Resources Bulletin, Vol. 8, No. 6, p 1273-1276, December, 1972. 2 fig, 9 ref.

Descriptors: *Sewage treatment, *Sewage disposal, *Waste water disposal, Pollution sources, Irrigation.

Over 23 billion gallons of sewage effluent are discharged in the United States each day. Increasing strict water quality laws make effluent irrigation more inviting. At an application level of two inches per week, 129 acres are required to dispose of one million gallons of waste water per day. Dangers do exist and are delineated. With careful planning and reconnaissance, the disposal site can be selected to allow for more favorable disposal and renovation potential through irrigation.

72-73:05E-002
AN ECONOMIC ANALYSIS OF SELECTED AGRICULTURAL USES OF WARM WATER IN THE PACIFIC NORTHWEST RESULTING FROM ELECTRIC POWER GENERATION,
Johns, R. W., Folwell, R. J., Dailey, R. R., and Wirth, M. E.
Washington State University, Department of Agricultural Economics, Pullman.
Journal of Environmental Quality, Vol. 2, No. 2, p 224-228, April-June, 1973. 1 fig, 4 tab, 16 ref.
(See 72-73:05B-089)

72-73:05E-003
INJECTION WELLS POSE A POTENTIAL THREAT,
Environmental Science and Technology, Vol. 6, No. 2, p 120-122, February, 1972. 3 fig.
(See 72-73:02F-084)

WATER QUALITY MANAGEMENT AND PROTECTION

WATER TREATMENT AND QUALITY ALTERATION (Group 05F)

72-73:05F-001
EVALUATION OF CURRENT TECHNIQUES FOR NUTRIENT REMOVAL FROM WASTEWATERS,
Shindala, A.
Mississippi State University.
Water Resources Bulletin, Vol. 8, No. 5, p 987-998, October, 1972. 32 ref.
(See 72-73:05D-005)

72-73:05F-002
ABSORPTION OF MERCURIC CATION BY TANNINS IN AGRICULTURAL RESIDUES,
Waiss, A. C., Jr., Wiley, M. E., Kuhnle, J. A., Potter, A. L., and McCready, R. M.
United States Department of Agriculture, Berkeley, California.
Journal of Environmental Quality, Vol. 2, No. 3, p 369-371, July-September, 1973. 5 tab, 15 ref.
(See 72-73:05D-006)

72-73:05F-003
NITRATE REDUCTION WITH SUBMERGED DRAINS,
Willardson, L. S., Meek, B. D., Dickey, G. L., and Bailey, J. W.
Imperial Valley Conservation Research Center, Brawley, California.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, p 84-90, January-February, 1972. 2 fig, 2 tab.

Descriptors: *Denitrification, *Anaerobic bacteria, *Water pollution sources, Drainage, Tile drainage, Submergence.

A field experiment has been installed in the San Joaquin Valley of California to test submergence of drains as a means of denitrification. Laboratory and field experiments have shown that denitrification occurs in saturated soil where there is ample organic carbon for bacterial metabolism and a shortage of oxygen. Denitrification and dilution of high nitrate ground water were accomplished in the field.

72-73:05F-004
NITRATE REMOVED AT WATER TREATMENT PLANT,
Gregg, J. C.
Sidney B. Bowne & Son, Mineola, New York.
Civil Engineering, Vol. 43, No. 4, p 45-47, April, 1973. 1 fig.

Descriptors: *Water treatment, Water quality, Water pollution sources, Nitrates, Ion exchange.

Rising nitrate content in the water supply in Long Island has become a problem, mainly due to sharply increasing population and the widespread use of septic tanks and cesspools there. In one water district, it was serious enough to shut down wells with a potential reduction of 60% in the area's water supply.

A solution seems to be found by adapting an ion exchange method to remove the nitrates from the water.

Section XXVIII

WATER QUALITY MANAGEMENT AND PROTECTION

WATER QUALITY CONTROL (Group 05G)

72-73:05G-001
POTENTIAL FOR CONTROLLING QUALITY OF IRRIGATION RETURN FLOWS,
Law, J. P., Jr., and Skogerboe, G. V.
Robert S. Kerr Water Research Center, Ada, Oklahoma.
Journal of Environmental Quality, Vol. 1, No. 2, p 140-145, April-June, 1972.
1 fig, 23 ref.

Descriptors: *Water quality control, *Irrigation efficiency, *Pollution abatement, Water conservation, Salinity, Nutrients, Pesticides, Soil erosion, *Return flow, Sediment transport.

Water quality problems associated with irrigation return flows are difficult to assess accurately and to control effectively. They include salinity increase, nutrient loss, sediment transport, and pesticide residue. The effects of these on the quality of receiving waters are discussed. Potential control measures that may prove effective in alleviating the detrimental effects of irrigation return flows are suggested. These may involve physical changes in the system, improvements in present management and cultural practices, or changes in the institutional influences upon the system. The potentials for improving the quality of return flows through changes in the water delivery system, farm water management practices, and water removal system are outlined and discussed. Research investigations will be required to further evaluate the effectiveness of many of the controls suggested.

72-73:05G-002
A MULTILEVEL APPROACH TO DETERMINING OPTIMAL TAXATION FOR THE ABATEMENT OF WATER POLLUTION,
Haimes, Y. Y., Kaplan, M. A., and Husar, M. A., Jr.
Case Western Reserve University, Cleveland, Ohio, Systems Engineering Division.
Water Resources Research, Vol. 8, No. 4, p 851-860, August 1972. 3 fig, 4 tab, 16 ref.

Descriptors: *Water quality control, *Pollution abatement, *Pollution taxes (Charges), *River basins, Optimization, Waste water treatment, Costs, Digital computers, Simulation analysis, Biochemical oxygen demand, Mathematical models, Systems analysis, Dissolved oxygen.
Identifiers: *Regional water quality management, *Miami River basin, Cost functions, Plant capacity, Treatment level, Polluters.

A three-level optimization approach is developed for regional water quality management. The problem of simultaneously finding an optimal waste water treatment configuration for meeting water quality standards along a river basin and determining optimal effluent charges to achieve this configuration is solved by decomposition and the multilevel approach. The optimal regional plant capacity and the regional treatment level are also found, depending on which polluters decide to use the regional facilities. (1) The individual polluters, (2) the regional treatment plant, and (3) the central authority are the three levels of optimization that are introduced for solution of the regional problem. It is assumed that the central authority does not need to know the local cost functions. Numerical results from simulated use of the technique with data for the Miami River basin reveal the efficiency and the effectiveness of the multilevel, hierarchical approach in the modeling, control, and management of regional water quality problems. Considerable savings over local treatment alone can be realized by employing regional treatment facilities.

72-73:05G-003
SALINITY AND SEDIMENTATION STUDY - COOPER RIVER REDIVERSION, CHARLESTON, SOUTH CAROLINA,
Jacobs, M. L.
Ellers, Reaves, Fanning and Oakley, Incorporated, Memphis, Tennessee.
Water Resources Bulletin, Vol. 8, No. 1, p 87-92, February 1972. 4 ref.

Descriptors: *Saline water intrusion, *Sedimentation, *Harbors, *Canals, *Reservoirs, Hydroelectric power, Hydraulics, Discharge (Water), Salinity, Wetlands, Water quality, Surveys.
Identifiers: *Charleston Harbor (SC).

Lakes Marion and Moultrie are located north of Charleston, S.C. on the Santee and Cooper Rivers, respectively. The impounded waters of both are utilized in the operation of generating plants and discharge into the Cooper River, the principal freshwater component of the Charleston Harbor.
Excessive sedimentation and pollution problems in the Charleston Harbor led to consideration of several rediversion plans. This study applies to diversion of the flow of the Cooper River through an artificial channel which would cross the saltwater marsh area between dykes and discharge into the Atlantic Ocean at right angles to the coast between jetties. Salinity will be significantly reduced in the areas on both sides of the rediversion channel. Significant sedimentation will occur in the areas on both sides of the rediversion channel. SEDIMENTATION DERIVED FROM THE SEAWARD DISCHARGE FROM THE DIVERSION JETTY SYSTEM WILL BE INSIGNIFICANT IN THE COASTAL MARSH AREAS NE of the rediversion channel and will be generally unimportant in the first decade or two of the life of the project SW of the channel. If the rediversion is to be seriously considered, the possibility of providing a barrier to density exchange should be investigated. In any case, a model study should be undertaken to establish quantitative values for consideration of those interested in the project.

72-73:05G-004
MATHEMATICAL PROGRAMMING FOR REGIONAL WATER QUALITY MANAGEMENT,
Graves, G. W., Hatfield, G. B., and Whinston, A. B.
California University, Los Angelos, School of Business.
Water Resources Research, Vol. 8, No. 2, p 273-290, April 1972. 13 fig, 12 tab, 5 ref.

Descriptors: *Estuary, *Water quality control, Delaware River Basin Commission, Optimization, Systems analysis, *Mathematical models, Water temperature, Biochemical oxygen demand, Dissolved oxygen, Flow, Linear programming, Model studies, *Regional analysis.
Identifiers: *Delaware Estuary, *Regional treatment systems, By-pass piping.

A mathematical model was developed to define minimum cost water quality control policies in the Delaware Estuary. Control alternatives included treatment at the waste source and by-pass piping with regional treatment. The model was solved using both linear and non-linear programming algorithms. A small-scale problem with five dischargers, three estuary sections, and three potential treatment plants was set up to illustrate the methodology used. The results indicated that a regional treatment system for the Delaware Estuary is less costly than other proposed schemes.

72-73:05G-005
PROGRESSIVE TAXATION AS A POLICY FOR WATER QUALITY MANAGEMENT,
Ferrar, T. A.
California University, Riverside, Department of Economics.
Water Resources Research, Vol. 9, No. 3, p 563-568, June 1973. 3 fig, 5 ref.

Descriptors: *Water resources, *Water quality, *Management, *Pollution taxes (Charges), *Water quality standards, Effluents, Pricing, Waste disposal, Resource allocation, Mathematical models, Systems analysis, Optimization.
Identifiers: *Cost minimization.

Recent literature on environmental control and water resources management has advocated the allocative efficiency associated with standard effluent taxation control measures. This article demonstrates that the operational characteristics of such techniques tend to render them impotent as standard maintenance measures. The significant operational weakness is a fundamentally static applicability. Since most acute environmental problems occur in vigorously developing metropolitan areas, the concept of a linear, static equilibrium charge is meaningless in such dynamic settings. A new, nonlinear effluent taxation structure is proposed that alleviates this weakness by incorporating a progressive taxation schedule that is tied to water quality standards. An allocation model is outlined, and the rationing procedure involves an incentive-feedback algorithm that iteratively allocates the available environmental resource among the polluters in accordance with a cost minimization objective.

72-73:05G-006
SEDIMENT CONTROL,
Bowen, D. K.
Soil Conservation Service, Washington, D. C.
Agricultural Engineering, Vol. 53, No. 7, p 17-19, July 1972.

Descriptors: *Sedimentation, *Sediment control, *Sediment discharge, *Maryland, *Regulation, Water pollution control, Water pollution sources.
Identifiers: Maryland Department of Natural Resources

The state of Maryland's decision processes and resultant laws concerning sediment control stemmed from the recognition that uncontrolled erosion is a hydraulic pollutant. Due to suburbanization, the Potomac River and Sligo Creek were altered by the sediment discharges from land clearing operations. Regulations to control sediment were developed and administered at the local level, with state 'oversight' providing uniformity between counties and comparable regulation for state agencies. County soil conservation districts handle the bulk of administration and enforcement, while the Maryland Department of Natural Resources handles the coordinating, regulating, and approval functions on a statewide level. The process and scope of Maryland's solution to sediment control is of value to any agency, county, or state devising such controls.

72-73:05G-007
MOVEMENT OF NITRATES UNDER IRRIGATED AGRICULTURE,
Edwards, D. M., Fischbach, P. E., and Young, L. L.
Nebraska University, Lincoln.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, p 73-75, January-February, 1972. 6 fig, 14 ref.
(See 72-73:05B-034)

72-73:05G-008
CHEMICAL AND BIOCHEMICAL CONSIDERATIONS FOR MAXIMIZING THE EFFICIENCY OF FERTILIZER NITROGEN,
Parr, J. F.
United States Department of Agriculture, Baton Rouge, Louisiana.
Journal of Environmental Quality, Vol. 2, No. 1, p 75-84, January-March, 1973.
6 fig, 2 tab, 56 ref.
(See 72-73:05B-046)

72-73:05G-009
NITROGEN-15 ENRICHMENT OF SOILS AND SOIL-DERIVED NITRATE,
Bremner, J. M., and Tabatabai, M. A.
Iowa State University, Ames.
Journal of Environmental Quality, Vol. 2, No. 3, p 363-365, July-September,
1973. 3 tab, 12 ref.
(See 72-73:05B-053)

72-73:05G-010
NITROGEN TRANSFORMATIONS IN SEDIMENTS AS AFFECTED BY CHEMICAL AMENDMENTS,
Chen, R. L., and Keeney, D. R.
Wisconsin University, Madison.
Water Resources Bulletin, Vol. 9, No. 6, p 1136-1144, December, 1973. 8 tab,
27 ref.
(See 72-73:02H-001)

72-73:05G-011
ESTIMATION THEORY APPLICATIONS TO DESIGN OF WATER QUALITY MONITORING SYSTEMS,
Moore, S. F.
Massachusetts Institute of Technology, Cambridge, Department of Civil Engineering.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol.
99, No. HY5, Proceedings paper No. 9755, p 815-831, May 1973. 8 fig, 6 tab,
9 equ, 12 ref.

Descriptors: *Water quality control, *Monitoring, *Stochastic processes, *Data collections, *Estimating, Hydraulics, Water quality standards, Economics, Optimization, Costs, Management, Mathematical models, *Design, Systems analysis, Equations, Aquatic environment.
Identifiers: *Data systems, Filtering techniques.

The objectives of water quality control are quantified in water quality standards, and enforcement of standards is the feedback mechanism for quality control. To achieve effective control, engineers need a knowledge of the state of the aquatic ecosystem. The necessary information is obtained from monitoring or data collection programs and an understanding of the phenomena involved (a model). A quantitative methodology, utilizing Kalman filtering techniques, is developed for designing water quality monitoring systems. A basis is established for: (1) Improvement of current practices of specification and enforcement of water quality standards; and (2) evaluating the economic tradeoff between temporal and spatial frequency of sampling. Monitoring systems are characterized by spatial and temporal frequency of sampling and the variables to be measured. Utilizing a dynamic model of the aquatic environment and estimates of the uncertainty in model error and measurement error, a best sampling program is selected from a set of feasible sampling programs by sequentially minimizing a specified measurement system cost function. An optimal solution is not guaranteed. The power of the technique is based on the unique combination of model and data obtained from filtering techniques. The major shortcomings are: (1) the need for a model of the systems and (2) high computer costs.

72-73:05G-012
COMPUTATIONAL RESULTS FOR WATER POLLUTION TAXATION USING MULTILEVEL APPROACH,
Haimes, Y. Y., Foley, J., and Yu, W.
Case Western Reserve University, Cleveland, Ohio, Systems Research Center.
Water Resources Bulletin, American Water Resources Association, Vol. 8, No. 4, p 761, 772, August 1972. 3 fig, 2 tab, 13 ref.

Descriptors: *Pollution taxes (Charges), Waste treatment, Waste water treatment, *Cost analysis, *Water quality control, *Water pollution control, Biochemical oxygen demand, Model studies, Mathematical models, Optimization, Theoretical analysis, Water pollution sources.
Identifiers: Multilevel mathematical approach.

A regional authority was postulated as a pollution abatement agency with the task of minimizing the total cost of waste treatment to the region. Data from the Miami River in Ohio are used to model a 27 reach river with 15 BOD dischargers. The multilevel approach with a 2 level optimization hierarchy is applied to the river system. At the first level each subsystem is independently optimized, and at the second level the subsystems solutions are coordinated to yield an overall optimum to the whole region. The initial level approach assumes a knowledge of the local treatment cost functions by the regional authority while the other approach assumes no such knowledge. Computational results are presented to complement the theoretical discussions on the multilevel approach.

72-73:05G-013
SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS 1970-1971, SECOND ANNUAL ISSUE,
Skogerboe, G. V., Walker, W. R., Meyer, D. J., and Bennett, R. S.
Colorado State University, Fort Collins, Department of Agricultural Engineering.
Environmental Protection Agency, Technology Series Report, EPA-R2-73-271, June 1973. 285 p.

Descriptors: *Fertilizers, Irrigated land, Irrigation systems, *Irrigation water, *Nitrates, *Phosphates, *Return flow, Salinity, Water pollution effects, Water pollution sources, Water quality control, Abstracts, *Bibliographies.

Research related to the quality of irrigation return flow is being conducted at numerous institutions throughout the western United States. Related work is also underway at other institutions in the United States, as well as other portions of the world. Approximately 100 sources of material have been searched for articles pertinent to the National Irrigation Return Flow Research and Development Program. These articles describe water quality problems resulting from irrigated agriculture, potential technological solutions for controlling return flows, recent research pertinent to return flow investigations, and literature associated with institutional constraints in irrigation return flow quality control. This second annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS contains approximately 450 abstracts of documents published in 1970 and 1971. Author and subject indexes are included.

72-73:05G-014
NUTRIENT BALANCE FOR THE EVALUATION OF NUTRIENT SOURCES IN WATER QUALITY MANAGEMENT,
Peters, R. H.
Department of the Environment, Water Quality Branch, Ottawa, Canada.
Water Resources Bulletin, Vol. 9, No. 1, p 49-53, February, 1973. 2 fig, 3 tab, 1 ref.
(See 72-73:05B-087)

72-73:05G-015
PREDICTION MODELING FOR SALINITY CONTROL IN IRRIGATION RETURN FLOWS,
Hornsby, A. G.
Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma.

Environmental Protection Technology Series Report EPA-R2-73-168, March 1973.
55 p, 6 fig, 101 ref.

Descriptors: *Irrigation systems, Surface flow, Subsurface flow, Salt movement, Ion exchange, System analysis, Water resources, Management, Evapotranspiration, Soil physical properties, Soil moisture, *Reviews, *Return flow, *Salinity, Model studies, *Water management (Applied).

A review of the current state-of-the-art of prediction modeling as applied to salinity control in irrigation return flows is presented. Prediction models are needed to assess the effects of proposed changes in irrigation management practices on the quality of return flows. The processes which affect salinity levels in return flows are enumerated and their interactions are alluded to. Models used to predict the quantity and quality of return flows are briefly discussed to show the development of the current level of technology. The readers are referred to the original documents for more rigid development of the models and incumbent assumptions. It was concluded that technology of water and salt flow in soil systems is sufficiently developed to permit formulation of models using systems analysis to evaluate proposed changes in management practices. Development of systems models to study irrigation return flow problems and conjunctive water resource uses was recommended.

72-73:05G-016
IRRIGATION MANAGEMENT FOR CONTROL OF QUALITY OF IRRIGATION RETURN FLOW,
King, L. G., and Hanks, R. J.
Utah State University, Logan, Department of Agricultural and Irrigation Engineering.
Environmental Protection Agency, Technology Series Report EPA-R2-73-265, June 1973. 307 p, 81 fig, 60 tab, 75 ref.

Descriptors: *Return flow, *Leaching, *Salinity, *Irrigation practices, *Colorado River Basin, Environmental effects, Water quality, Irrigation, Drainage, Soil water, Management, Drainage effects, Computer models, *Model studies, *Utah.
Identifiers: Return flow quality, On-farm water management, Salt storage, Irrigation scheduling, Salt movement, Irrigation frequency, Irrigation management, Field irrigation studies, Ashley Valley (Utah).

Field studies tested the possibilities for using the unsaturated soil profile including the crop root zone as a temporary salt reservoir and providing excess water for leaching and salt discharge when desired. Two models were developed for describing flow of water and salt through the soil with extraction of water by evapotranspiration. One model was designed for use as an irrigation management tool while the other model was initially intended to provide a detailed understanding of the water and salt flow through the soil. The best management model will probably result from a combination of the two models described. Timing of irrigation was tested as a management variable. With all other conditions the same, the model predicts that as the time interval between irrigations increases, the season totals of salt removed from the root zone, salt remaining in the profile, and water required for leaching tend to level off. However, the irrigation frequency has a significant effect upon when the salt is discharged during the season. Results indicate that managing irrigation for control of return flow quality requires good control of depth and timing of irrigation. Some needs for further research are given.

Section XXIX

WATER RESOURCES PLANNING

TECHNIQUES OF PLANNING (Group 06A)

72-73:06A-001
ALGEBRAIC TECHNOLOGICAL FUNCTION FROM A SIMULATION MODEL,
Maddock, T., III
Harvard University, Cambridge, Massachusetts
Water Resources Research, Vol. 8, No. 1, p 129-134, February 1972. 2 fig, 2 tab, 8 ref.

Descriptors: *Simulation analysis, *Systems analysis, *Optimization, *Economics, *Water costs, Cost-benefit analysis, Water management (Applied), Irrigation water, Parametric hydrology, Mathematical models.

Distributed-parameter models for groundwater simulation are difficult to couple explicitly with management models that seek to optimize an economic objective. For a groundwater system whose drawdown in response to pumping was modeled by a two-dimensional linear partial differential equation, an algebraic technological function was produced that related seasonal pumping at wells in the system to drawdown at those wells. The algebraic technological function allows explicit coupling of the groundwater model with a quadratic programming management model.

72-73:06A-002
DYNAMIC MULTISECTOR PROGRAMMING APPROACH TO REGIONAL WATER RESOURCE MANAGEMENT,
Bargur, J.
Tahal Consulting Engineers Limited, Tel-Aviv (Israel), Research and Development Division.
Water Resources Research, Vol. 8, No. 4, p 801-817, August 1972. 3 fig, 5 tab, 15 ref.

Descriptors: *Water management (Applied), *Planning, *Regional analysis, Water resources, Resource allocation, Optimization, Linear programming, *California, Systems analysis, Model studies.
Identifiers: Equilibrium analysis.

In arid and semiarid areas, water is scarce and requires an intersectoral, intertemporal, and sometimes interregional planning approach to insure its efficient use and allocation among the competing factors. In most cases, the water scarcity is an economic phenomenon that is partially determined by the costs of undertaking water development and water transfer projects. Presented is a multisector planning and management approach to water resources that is based on a general equilibrium analysis using input-output models and linear programming techniques. A dynamic multisector programming model that takes into account the sectoral, spatial, and temporal aspects of regional planning and an extension to an activity analysis model are formulated and applied empirically to California and the western United States for a 15-year planning horizon. Results include water requirement forecasts, interregional water transfer requirements, efficient production and cropping patterns, 'shadow prices' for water and labor, and an optimal investment program for water resource projects. Using a general equilibrium programming model makes it possible to investigate problems of regional development that are dependent on the interrelationships between resource availabilities and sectoral planning and illustrates the importance of the complex interdependencies among economic variables.

72-73:06A-003
COMBINED USE OF OPTIMIZATION AND SIMULATION MODELS IN RIVER BASIN PLANNING,
Jacoby, H. D., and Loucks, D. P.
John F. Kennedy School of Government, Cambridge, Massachusetts.
Water Resources Research, Vol. 8, No. 6, p 1401-1414, December, 1972. 3 fig, 27 equ, 15 ref.

Descriptors: *Optimization, *Simulation analysis, *River basins, *Planning, *Computer programs, *Delaware River, Digital computers, Alternative planning, Mathematical models, Systems analysis.

Simulation models have proved to be extremely useful in aiding river basin planning. However, all suffer a common difficulty, since the analyst himself must formulate the physical design to be studied in each computer run. If the basin is large and offers a variety of development opportunities, the number of alternative system plans from which he must choose can be extremely large. An investigation is reported of the use of analytical optimization models to 'screen' the set of possible plans and to select a small number worthy of simulation analysis. Deterministic and stochastic optimization models have been developed and applied to both static and dynamic (multi-period) planning problems; the Delaware River basin is used as an example. The resulting designs have been analyzed by using a large-scale digital simulation model of the basin so that the ability of the screening models to identify high-valued alternatives can be evaluated. In this context the results indicate considerable promise for the combined use of optimization and simulation models.

72-73:06A-004
IMPROVED RIVER BASIN UTILIZATION THROUGH SYSTEMS ANALYSIS,
Foster, E. T., Jr., Chen, T. C., Newton, J. P., and Isu, E. O.
HDR Systems, Omaha, Nebraska.
Water Resources Bulletin, American Water Resources Association, Vol. 8, No. 5, p 863-870, October, 1972. 2 fig, 3 tab, 18 equa, 14 ref.

Descriptors: *Water distribution (Policy), *River basins, Management, Operations, Facilities, Optimization, *Linear programming, *Montana, *Missouri River basin, *Decision making, Systems analysis, Mathematical models, Reservoirs, Diversion structures, Dams, Constraints, Equations.
Identifiers: Objective functions, *Marias River basin, *Milk River basin.

Theoretical and practical results are examined for a study to determine optimal water resource allocation in the 30,000-square-mile Montana North Central Conservancy District. The district covers several river basins and contains numerous existing and proposed facilities (dams, reservoirs, and diversion canals). The study determined the operation of all these facilities along with the sizing of the proposed facilities in order to optimize given objective functions. Related efforts in optimal river basin utilization were surveyed, and linear programming was selected as an expedient optimization technique. Herein, the problem is formulated by identifying time stages which together constitute a repetitive cycle such as a year. With these stages, it is possible to associate operational and capacity variables with network components, which are branches or nodes. Objective functions are assembled for the component variables. Constraint equations are written in terms of the variables to reflect network nodal continuity, capacity restrictions, and adjudications such as water rights. A numerical example is considered in which the existing and proposed facilities are aggregated to produce a small, tractable number of facilities. Linear programming is shown to be quite feasible as a decision making technique for optimum water resource utilization.

72-73:06A-005

WATER PRODUCTION FUNCTIONS AND IRRIGATION PROGRAMMING FOR GREATER ECONOMY IN PROJECT AND IRRIGATION SYSTEMS DESIGN AND FOR INCREASED EFFICIENCY IN WATER USE,
Stewart, J. I., Hagen, R. M., Pruitt, W. D., and Hall, W. A.
California University, Department of Water Science and Engineering, Riverside.
Report No. 14-06-D-7329, United States Bureau of Reclamation, Denver, Colorado,
March 1973. 165 p, 21 fig, 15 tab, 3 append.

Descriptors: *Water utilization, Irrigation, Water management (applied), Water requirements, Evapotranspiration, Economic feasibility.

A continuing long term study aimed at quantitative prediction of relations between yields of principal crops and water is reported. Results of four years of field experiments on corn and two years on grain sorghum are included, along with conceptualization and detailed methodology of a comprehensive approach to planning the use of water in agriculture. The method combines researched genetic characteristics of crops with planned irrigation site measurements of climate, soil and irrigation capabilities to estimate quantitatively:

(1) Generalized relative value functional relations between yield and evapotranspiration of given crop varieties.
(2) Generalized absolute value yield vs. evapotranspiration functions for given crop varieties in measured evaporative conditions.
(3) Absolute value yield vs. irrigation (season depth) functions for given crop varieties in measured conditions of climate, soil, and irrigation capability.
(4) Optimal programs of dates and depths of irrigation suited to given crop varieties in measured environments.

Section XXX

WATER RESOURCES PLANNING

EVALUATION PROCESS (Group 06B)

72-73:06B-001
LEARNING, EXTERNAL BENEFITS, AND SUBSIDES IN WATER DESALINATION,
Rausser, G. C., Willis, C., and Frick, P.
California University, Davis, Department of Agricultural Economics.
Water Resources Research, Vol. 8, No. 6, p 1385-1400, December, 1972. 1 fig, 7 tab, 12 equ, 2 append, 33 ref.

Descriptors: Water resources, *Desalination, *Investment, *Decision making, *Costs, Estimating, Sea water, *Simulation analysis, Computers, Mathematical models, Systems analysis.
Identifiers: Learning, *External benefits, *Subsidies, Bayesian methods, Distillation plants.

In the absence of the recognition of learning in new technologies such as desalting, water resources investment decisions may be erroneous for two reasons. First, neglecting cost reductions over time due to 'learning by doing' leads to the overestimation of costs. Second, since learning in a particular desalting plant may result in external learning benefits to other plants, these externalities may serve as the basis for the determination of a subsidy intended to internalize these benefits. Estimates of learning (cost) functions for largescale seawater distillation plants are provided. To incorporate prior information into the estimation process, Bayesian methods are used. Alternative specifications of these learning functions are then employed in the context of a measure of external learning benefits to estimate by computer simulation the moments of these benefits. The employing of such a measure in various water resource decision models is discussed. It is obvious that the estimates of external learning benefits provided can be introduced into investment-sequencing models that seek to optimize the sequencing and timing of a number of alternative projects.

72-73:06B-002
A SIMULATED ENVIRONMENTAL MODEL OF TEMPERATURE, EVAPORATION, RAINFALL, AND SOIL MOISTURE,
Jones, J. W., Colwick, R. F., and Threadgill, E. D.
United States Department of Agriculture, State College, Mississippi.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 366-372, March-April, 1972. 8 fig, 2 tab, 24 ref.
(See 72-73:02A-006)

Section XXXI

WATER RESOURCES PLANNING

WATER DEMAND (Group 06D)

72-73:06D-001
INTEGRATION OF THE AGRICULTURAL DEMAND FUNCTION FOR WATER AND THE HYDROLOGIC MODEL OF THE PECOS BASIN,
Gisser, M., and Mercado, A.
New Mexico University, Albuquerque, Department of Economics.
Water Resources Research, Vol. 8, No. 6, p 1373-1384, December, 1972. 1 fig, 7 tab, 2 append, 8 ref.

Descriptors: Economics, *Parametric hydrology, Agriculture, *Water demand, *Imported water, *Costs, *Estimating, *Linear programming, *Artificial recharge, *New Mexico, Systems analysis, Mathematical models, Pumping, Water table, Discharge (Water), Irrigation, Confined water, Shallow water, Equations, Forecasting.
Identifiers: *Pecos River basin, *Demand function, Roswell basin, San Andres aquifer.

The result of integrating the agricultural sector with the aquifer of the Pecos basin is presented. In particular, steady state solutions to hydrologic and economic equations are given in which imported water is artificially recharged to the aquifer and its cost is combined with the cost of pumping. A two-cell model (consisting of five equations) for the Pecos basin aquifer is developed, which yields optimal steady state solutions for a variety of prices of imported water. One cell is for the confined aquifer and the other is for the shallow aquifer. The hydrologic solution of the model yields two linear steady state functions that relate the water table in the two cells to other hydrologic variables, such as recharge, discharge, and irrigation. The cost of pumping water is also estimated. The agricultural demand function for irrigation water is empirically estimated by applying parametric linear programming. The demand function for water is linked to the water table hydrologic equations. Solutions are found for a range of expected prices of imported water. Two basic assumptions underlie this study: 1) Imported water will be artificially recharged into the ground; and 2) farmers will pay the full price of imported water.

72-73:06D-002
NATIONAL AND INTERREGIONAL MODELS OF WATER DEMAND, LAND USE, AND AGRICULTURAL POLICIES,
Heady, E. O., Madsen, H. C., Nicol, K. S., and Hargrove, S. H.
Iowa State University, Ames, Department of Economics.
Water Resources Research, Vol. 9, No. 4, p 777-791, August 1973. 10 fig, 2 tab, 11 ref.

Descriptors: *Mathematical models, *Water demand, United States, *Land use, *Agriculture, *Resource allocation, *Water supply, *Pricing, Marketing, Irrigation water, Regions, Human population, Crops, Foods, Fiber crops, Reservoirs, Economics, Equations, Systems analysis, Optimization, Planning.
Identifiers: Interregional analysis, Cost minimization.

A study is presented of the optimum allocation of land and water resources in 223 agricultural land regions, 51 water supply regions, and 27 market regions of the United States. The study is built upon a family of programming models which incorporate all major U.S. agricultural commodities into a supply-demand and resource use interaction, and endeavors primarily to determine whether or under what conditions the nation has enough water to produce its future food and fiber requirements under urban and industrial water demands reflected in various levels and distributions of population and national economic activity in the year 2000. The amount of water used in agriculture is partly a function of the prices of water for irrigation; hence an auxiliary objective is to formulate models to reflect (normatively) the demand for water under different pricing policies. Analyzed are the impacts of future alternatives on the demand for water, such as water prices, population levels, farming technology, export quantities, and agricultural policies. In general, results show that, if agricultural and water development policies were changed over the future, the nation would not be faced with an overall water scarcity, and even surplus food producing capacity could exist with the use of less water for agricultural purposes.

72-73:06D-003
LAND USE TRENDS AND THE FUTURE OF AGRICULTURE IN THE NORTH ATLANTIC REGION,
Zube, E. H.
Massachusetts University, Department of Landscape Architecture and Regional Planning, Amherst.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 232-234, 238, March-April, 1972. 10 ref.

Descriptors: *Land use, Land management, Land development, Rural areas, Urbanization, Zoning.

A literature review study showing that agricultural and open land will decrease by as much as 50% by the year 2020 if present trends continue. An argument for keeping pure land is also presented.

Section XXXII

WATER RESOURCES PLANNING

WATER LAW AND INSTITUTIONS (Group 06E)

72-73:06E-001
GENERAL STATEMENT OF PRINCIPLES TO BE INCLUDED IN STATE WATER RIGHTS LAWS.
American Society of Civil Engineers, New York, Committee on Water Laws.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR2, p 317-322, June 1972.

Descriptors: *Water rights, *Appropriation, *Adjudication procedure, State jurisdiction, Groundwater, Water quality, Controlled drainage, Prior appropriation.

This is a consensus report that has been in preparation since March, 1965. Its primary purpose is to allow and encourage others to enter in formalized Discussion. After the Discussion is closed the Committee will consider all suggestions before preparing a final statement. Items covered include policy objectives, vested rights, fundamental principles of priority, water filings, appropriation limited to specific quantity, completion of work, proof of beneficial use, adjudication, forfeiture, change in point of diversion, eminent domain, groundwater, water quality, drainage requirements, safety of structures, administration and interstate water resources. The principle of priority should be followed in all circumstances, limitations should be placed on the use of water in exercising basic rights and time limits should be set for beneficial use. Other main points made are that groundwater appropriation should follow the same general principles as surface water, states should set quality standards and interstate water resources should be governed by interstate compacts.

72-73:06E-002
STATE WATER RIGHTS LAWS,
Walker, W. R.
Virginia Polytechnic Institute and State University, Blacksburg.
Preprint No. 1908, American Society of Civil Engineers, National Water Resources Engineering Meeting, Washington, D.C., January 29-February 2, 1973. 12 p.

Descriptors: *Water rights, *Water allocation, *Prior appropriation, *Water law, Competing uses, Appropriation, Beneficial use, Legal aspects.
Identifiers: *Committee on Water Laws (ASCE).

The Committee on Water Laws of the Irrigation and Drainage Division of the American Society of Civil Engineers has suggested that states declare a water use policy. The Committee has developed a general statement for a recommended policy for adoption by the states. This policy declares that all water in its natural environment is part of the public wealth and that it is a natural resource subject to appropriation. Implicit in this statement is the declaration that the appropriation doctrine, as applied in the western United States, should be adopted by all states. This doctrine recognizes three distinct elements--diversion, reasonable beneficial use, and private property. This publication questions the desirability of accepting western water right appropriation doctrines universally and, to some extent, the desirability of the continued application of this doctrine in the West. For example, under present appropriation laws, the use of water for maintaining low streamflows to protect fish life and provide recreation was found not to be a valid appropriation because an actual diversion was not necessary. Many other problems exist in deciding the best possible beneficial use of desired diversions and in the length of time the appropriations are granted.

72-73:06E-003
INTERSTATE AND INTERNATIONAL AQUIFERS,
Bittinger, M. W., and Jones, E. B.
M. W. Bittinger and Associates, Incorporated, Fort Collins, Colorado.
Water Resources Bulletin, Vol. 8, No. 2, p 386-390, April, 1972. 11 ref.

Descriptors: *Groundwater, *Aquifers, Interstate, International waters, Water law, Water utilization.

Many important groundwater aquifers cross state and national boundaries. The flow of water in these aquifers is not influenced by the boundaries but may be materially influenced by man's activities on one or both sides of a boundary. Interstate and international problems may develop because of excessive groundwater lowering on one side of a boundary affecting water users on the opposite side of the line. Similarly, intensive groundwater development along a surface stream may influence the amount of surface water that flows across a boundary. A third type of problem may develop when pumping on one side of the boundary induces poor quality water into an aquifer on the other side of the boundary. Several specific interstate and international aquifer problems are briefly described.

72-73:06E-004
INSTITUTIONAL CONSTRAINTS ON AGRICULTURAL WATER USE,
Ward, R. C., Skogerboe, G. V., and Walker, W. R.
Colorado State University, Agricultural Engineering Department, Fort Collins, Colorado.
Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-14, 1973. Chicago, Illinois. 18 p, 18 ref.

Descriptors: *Water utilization, *Agriculture, Institutional constraints, Law enforcement.

Scarcity of water in the western United States has resulted in the development of a vast institutional framework to insure its just allocation. The institutions are briefly reviewed, and their impact on agriculture's water use is discussed.

72-73:06E-005
WATER LAW AND THE HYDROLOGIC CYCLE: A TEXAS EXAMPLE,
Templer, O. W.
Texas Tech University, Department of Geography, Lubbock.
Water Resources Bulletin, Vol. 9, No. 2, p 273-283, April, 1973. 2 fig, 39 ref.

Descriptors: *Water law, *Legislation, *Texas, Riparian rights, Groundwater, Hydrologic cycle, Water rights, Water utilization, Water wells, Water yield.

The law divides water in the cycle into several different classes. Each is treated separately and generally without consideration of interconnections existing within the cycle. Different rules of law have arisen concerning the ownership and use of each legal class. Under Texas law several classes of surface and ground water are recognized, and weather modification efforts bring yet another class, atmospheric moisture, under consideration. It is instructive to follow water moving through the hydrologic cycle in the Nueces River basin, Texas, as a framework for discussing the substantial interconnections between the various legal classes of water and the difficulties that arise from attempts to apply different rules of law to each class. Strictures imposed by Texas water law can seriously interfer with coordinated, efficient use and management of water resources, as evidenced by the Nueces River basin. Well-recognized, existing water rights in the several phases of the hydrologic cycle make change of these institutional constraints difficult to achieve.

Section XXXIII

WATER RESOURCES PLANNING

ECOLOGIC IMPACT OF WATER DEVELOPMENT (Group 06G)

72-73:06G-001
SOIL AND WATER CONSERVATION RESEARCH: CHALLENCE FOR THE 70'S,
van Schilfgaarde, J.
United States Department of Agriculture, Agricultural Research Service, Beltsville, Maryland.
Agricultural Engineering, Vol. 54, No. 4, p 17, 20, April, 1972.

Descriptors: *Conservation, Soil conservation, Water conservation, Research priorities.

Article consists of a talk presented by the author concerning the research needed in agriculture during the 1970's. Figures of work already done presented and an outline of needed research is made.

Section XXXIV

RESOURCES DATA

DATA ACQUISITION (Group 07B)

72-73:07B-001
AUTOMATIC SAMPLER FOR DYE TRACER STUDIES,
Kilpatrick, F. A.
Geological Survey, Washington, D.C., Water Resources Division
Water Resources Research, Vol. 8, No. 2, p 737-742, June 1972. 4 fig, 7 ref.

Descriptors: *Sampling, *Dye releases, *Tracers, Tracking techniques, Dye dispersion, Dye concentrations, Automation.

A simple, largely mechanical device for automatically collecting periodic discrete water samples for use in dye tracer studies has been developed and successfully used by the U.S. Geological Survey. The device consists essentially of two rows of spring-loaded hypodermic syringes that are released from their closed position at selected time intervals to draw in and retain the desired water samples. The sampler is mounted in a boatlike structure partially immersed in the flow to be sampled.

72-73:07B-002
SOIL SURFACE WATER DEPLETION AND LEAF TEMPERATURE,
Aston, A. R., and Van Bavel, C. H. M.
Texas A and M University, College Station, Remote Sensing Center.
Agronomy Journal, Vol. 64, p 368-373, May-June 1972. 7 fig, 7 ref.

Descriptors: *Soil temperature, *Surface waters, *Environmental effects, *Drying, *Soil environment, *Thermal radiation, Leaves, Agronomy, Crop production, Soil investigations, Analytical techniques, Energy budget, Soil-water-plant relationships, Evapotranspiration, Soil surfaces, Crop response, Thermal stress, Microenvironment, Standing waters, Plant physiology, Water loss, Remote sensing.
Identifiers: Leaf energy budget.

In any attempt to arrive at a useful application of remote sensing techniques in agricultural crop production, a particular radiance or radiance pattern must be uniquely related to a condition of interest in the soil-crop system. This work explores the feasibility of the remote detection of water depletion in a cropped field. It proposes that this may be accomplished by detecting the increase in the visible and thermal radiant heat loads upon plant leaves when the underlying soil surface dries. A theoretical model was constructed, relating leaf temperature to soil surface temperature. Parallel experiments were done using a grey podzolic soil. In spite of an increase of 15 percent in reflectivity upon drying, there was an increase in soil surface temperature from 20 to 50 C. The increased shortwave and longwave radiant loads on leaf arrays in the experiments resulted in leaf temperature increases of 2.5, 0.5, and 2 C in dry blotting paper, wet blotting paper, and leaves of the southern pea (Vigna sinensis), respectively. The leaf energy balance-soil water depletion model predicted these increases, as well as the absolute temperature, with an accuracy of 1 and 5 percent for the artificial and real leaves, respectively. Findings affirm that a technology can be developed for the remote detection of soil water depletion in field crops, but that the temperature differences involved are both small and variable.

72-73:07B-003
AERIAL THERMAL SCANNER TO DETERMINE TEMPERATURES OF SOILS AND OF CROP CANOPIES DIFFERING IN WATER STRESS,
Bartholic, J. F., Namken, L. N., and Wiegand, C. L.
Florida University, Gainesville, Department of Climatology.
Agronomy Journal, Vol. 64, No. 5, p 603-608, 1972. Illus.

Identifiers: *Aerial thermal scanner, *Crop canopies, Gossypium-hirsutum, *Soils, *Temperatures, Water stress.

An airplane-mounted thermal scanner was used to measure irradiance in the 8- to 14-micrometer wavelength interval over an extensively instrumented agricultural area. The area included soils differing in water and tillage condition, and replicated cotton (Gossypium Hirsutum L.) plots with a wide range of plant water stress. The scanner data were recorded on analog magnetic tape and on 70-mm film. The film densities of the various soil and cotton treatments and film calibration information were determined with a microdensitometer. The observed irradiances corresponded to cotton plant canopy temperature differences up to 6 C between the most and the least water-stressed plots. The irradiance data from soils showed large differences as a function of time after tillage and irrigation. Thermal imagery offers potential as a useful aid for delineating water-stressed and nonstressed fields, evaluating uniformity of irrigation, and evaluating surface soil water conditions.

72-73:07B-004
AN IMPROVED VARIABLE-INTENSITY SPRINKLING INFILTROMETER,
Rawitz, E., Margolin, M., and Hillel, D.
Hebrew University, Jerusalem (Israel), Department of Soil Science.
Soil Science Society American Proceedings, Vol. 36, No. 3, p 533-535, 1972. Illus.

Identifiers: *Instrumentation, Flow, Infiltration, *Infiltrometers, Intensity, Movement, Rain, Simulator, Soils, Sprinkling.

Improvements of the Purdue-Wisconsin infiltrometer are described. A winch was added to the tower to facilitate assembly and the windshield was redesigned. Water distribution was improved by changes in the revolving shutter and the surplus water collection trough. The nozzle mounting was simplified, and water level in the vacuum runoff tank was transmitted to an external recorder. Good uniformity was obtained over a wide range of application rates.

72-73:07B-005
AUTOMATED FLOW-RECORDING SYSTEM FOR FIELD DRAINAGE MONITORING--DIRECT DATA COMPILATION OF SURFACE AND SUBSURFACE DRAIN FLOW,
Bornstein, J., Preston, H. A., Winant, W. M., and Benoit, G. R.
United States Department of Agriculture, Agricultural Research Service, South Burlington, Vermont.
Journal of Agricultural Engineering Research, Vol. 18, No. 1, p 31-35, March, 1973. 3 fig, 4 ref.

Descriptors: *Drainage, *Flow measurement, *Data collections, Data storage and retrieval, Data transmission, Data processing.

An automatic recording console has been developed to accept water stage data from remote weirs and flumes and store the data on magnetic tape. The sensingtransmitting-cycling-recording components can economically replace the mechanical-manual systems for converting flow events to card or tape data ready for computer analysis. A sequence of problems that had prevented operation was solved and is reported herein.

Section XXXV

RESOURCES DATA

EVALUATION, PROCESSING AND PUBLICATION (Group 07C)

72-73:07C-001
HYMO, A PROBLEM-ORIENTED COMPUTER LANGUAGE FOR BUILDING HYDROLOGIC MODELS,
Williams, J. R., and Hann, R. W.
Agricultural Research Service, Riesel, Texas, Soil and Water Research Division.
Water Resources Research, Vol. 8, No. 1, p 79-86, February 1972. 1 fig, 1 tab,
13 ref.

Descriptors: *Programming languages, *Computer programs, *Mathematical models, *Rainfall-runoff relationships, *Routing, Flood routing, Model studies, Systems analysis, Stage-discharge relations, Hydrographs.
Identifiers: Computer languages, Hymo.

Hymo is a computer language which can be used to great advantages in watershed modeling. Twelve commands, commonly used in hydrology, transform rainfall into runoff hydrographs and route these hydrographs through streams and valleys or reservoirs. These functions make Hymo quite useful in the design and evaluation of flood control structures, flood forecasting, and research studies. The procedures used in Hymo were selected because of their accuracy, simplicity, and practicality. The input data required for Hymo are normally available for most watersheds. Hymo is quite flexible in that hydrologists familiar with Fortran 4 programming can easily add new commands or modify the present commands.

Section XXXVI

ENGINEERING WORKS

STRUCTURES (Group 08A)

72-73:08A-001
COMPARISON OF STRENGTH TEST METHODS FOR CORRUGATED PLASTIC DRAINAGE TUBING,
Soribe, F. I., Fouss, J. L., and Schwab, G. O.
Ohio State University, Columbus.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 445-447, May-June, 1972. 8 fig, 8 ref.
(See 72-73:02F-062)

Section XXXVII

ENGINEERING WORKS

HYDRAULICS (Group 08B)

72-73:08B-001
GENERALIZED DISCHARGE RELATIONS FOR CUTTHROAT FLUMES,
Skogerboe, G. V., Bennett, R. S., and Walker, W. R.
Colorado State University, Fort Collins.
Journal of Irrigation Drain Division, American Society of Civil Engineers,
Vol. 98, No. IR4, p 569-583, December 1972. 11 fig, 2 tab, 5 ref, 2 append.

Descriptors: Irrigation, Open channel flow, *Discharge measurement, *Water measurement, Drainage, Flow measurement, Flumes, Design criteria, Hydraulic structures, Subcritical flow, Laboratory tests, Discharge coefficient, Fluid mechanics.
Identifiers: *Cutthroat flumes, Hydraulics, Measuring instruments, Parshall flumes, Submerged flow, Free flow.

The Cutthroat flume, a new flume designed to measure flows in flat gradient streams, is simple and economical, operates well under submerged flow conditions, and has low head loss. Initial investigations of the flume were limited to one length of 9 ft with throat widths ranging from 1 to 6 ft, and therefore, were not geometrically similar. To obtain generalized discharge rating curves for geometrically similar flumes, a group was rated under both free flow and submerged flow conditions. Twelve flumes were used in the study - 3 flumes lengths, 1.5, 3, and 4 ft, with 4 different throat widths for each length. In addition, the flume sizes were selected to permit correlations with the initial Cutthroat flume studies. To obtain the most accurate rating, based upon analysis of data scatters of laboratory ratings, flumes with throat width to length ratios between 0.1 and 0.4 are recommended. Because of scale effects, flumes less than 3 ft long are satisfactory only for free flow operations. Experimental flume dimensions are given; free flow and submerged flow coefficients and exponents are tabulated.

72-73:08B-002
ANALYTICAL FLOW NETS IN CHANNEL SEEPAGE FLOWS,
Bruch, J. C., Jr., and Fernandez Sainz, L. B.
California University, Santa Barbara, Department of Mechanical Engineering.
Water Resources Research, Vol. 8, No. 2, p 519, 524, April 1972. 9 fig, 10 ref.

Descriptors: *Surface-groundwater relationships, *Groundwater movement, *Alluvial channels, *Flow nets, Equations, Seepage, Infiltration, Canal seepage, Open channels.

An analytical solution technique to determine streamlines and equipotential lines in steady two-dimensional seepage from a single triangular channel into a permeable soil underlain at a finite depth by a drain was obtained by using conformal mapping. The technique was applied to triangular channels having side slopes of 45 deg. The results were compared with those from a published finite difference solution. The complex integrations were computed by using an interactive on line computer system. This computational method proved extremely easy to apply and a rapid means of obtaining accurate results.

72-73:08B-003
SEDIMENT CONTROL METHODS: B. STREAM CHANNELS.
American Society of Civil Engineers, New York, Hydraulics Division.
Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 98, No. HY7, Paper 9071, p 1295-1326, July 1972. 15 fig, 58 ref.

Descriptors: *Sediment control, *Sediment transport, *Sedimentation, *Erosion, Sediments, Streams, Channel erosion, Alluvial channels, Sediment load, Sediment yield.

General knowledge of control of erodible stream channels based on experience is summarized. Natural and artificial erodible channels are classified, the types of problems encountered in their control are described and solutions are outlined. The problems are reviewed in terms of principles, and solutions which have been successful are described and explained in terms of principles.

72-73:08B-004
EFFECT OF ROUGHNESS ELEMENTS ON HYDRAULIC RESISTANCE FOR OVERLAND FLOW,
Kowobari, T. S., Rice, C. E., and Garton, J. E.
Soil Testing Services Incorporated, Northbrook, Illinois.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 979-984, September-October, 1972. 4 fig, 4 tab, 8 ref.

Descriptors: *Hydraulics, *Open channel flow, *Manning's equation, Fluid mechanics, Open channels, Hydraulic models, Head loss, Roughness (hydraulic).

Gradually-varied flow experiments were conducted in a 1.32 foot by 24 foot long test section of a 44 foot long WF steel beam channel. The bottom was lined with aluminum sheet material which was fitted with round aluminum pegs of sizes 3/32 in. and 9/32 in. diameters. The pegs, which served as roughness elements, were placed in the channel bed at definite longitudinal and transverse patterns and spacings. Under the bare channel lining condition, a maximum flow of 0.885 cfs was introduced into the channel. Test slopes for the adjustable slope channel were restricted to approximate values of 0.0025, 0.0050 and 0.010. The objective was to determine the relationship of Manning's resistance coefficient to size of roughness elements, pattern of arrangement, density of spacing, slope, and discharge in a smooth artificial channel using dimensional analysis and gradually-varied flow. High correlations between calculated and observed values of the resistance coefficient were observed for all of the model equations.

72-73:08B-005
DESIGN CRITERIA FOR IRRIGATION SYSTEMS WITH COMPLEX PIPE LOOPS,
Edwards, D. M., and Spencer, B.
Nebraska University, College of Engineering and Architecture, Lincoln.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, p 76-78, January-February, 1972. 3 fig, 1 tab, 7 ref.

Descriptors: *Irrigation engineering, *Irrigation design, *Sprinkler irrigation, Pipe flow, Pipelines, Hydraulics, Fluid mechanics, Irrigation systems, Irrigation practices.

A design procedure is presented for the analysis of irrigation systems utilizing loop networks. The design of these systems are readily adapted to the digital computer. With the advent of solid set sprinkler, subsurface, and trickle irrigation systems the simple system layout may no longer be an adequate design. In these cases loop networks will lower fixed and operation irrigation costs while developing better water distribution by maintaining more uniform pressures throughout the system. This design procedure has been used successfully in actual field installations it should be emphasized that although the procedure produces very reliable results, the results of the entire analysis is only as good as the initial selection of inputs and outputs and human judgments.

72-73:08B-006
HYDRAULICS OF A CENTER PIVOT SYSTEM,
Chu, S. T., and Moe, D. L.
South Dakota State University, Agricultural Engineering Department, Brookings.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 5, p 894-896, September-October, 1972. 3 fig, 1 tab, 4 ref.

Descriptors: *Fluid mechanics, *Pipe flow, *Head loss, Irrigation practices, Sprinkler irrigation, Hydraulics, Closed conduits, Pressure conduits, Water distribution (applied), Application methods.
Identifiers: Center pivot system.

The analytical solutions for the total pressure head loss and the distribution of pressure head loss along the mainline of a center pivot system are presented. It is shown that the theoretical results are good approximations of practical field situations. Comparisons of theoretical values and field data are also presented.

72-73:08B-007
HYDRAULIC ROUGHNESS OF CORRUGATED PLASTIC TUBING,
Irwin, R. W., and Tsang, G.
Guelph University, School of Engineering, Guelph, Ontario, Canada.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 2, p 290-291, 295, March-April, 1972. 3 fig, 1 tab, 10 ref.

Descriptors: *Plastic pipes, *Tile drains, *Subsurface drains, Hydraulic conduits, Closed conduits, Fluid friction, Hydraulic design, Reynolds number, Roughness (hydraulic), Turbulence.
Identifiers: *Corrugated plastic tubing.

The functional relationships between frictional factor, Reynolds number, and relative roughness are determined for corrugated plastic drainage tubing. All tubing used was unperforated 4-inch diameter. The test section was 50 feet in length minus 10 feet at the inlet and 5 feet at the outlet allowed for end effects. The tubing was maintained full at all flow rates. Friction factors for corrugated tubing are about twice as great as for well laid tile. A single value to indicate pipe roughness for hydraulic design cannot be used for corrugated plastic tubing. A value specific to the tubing used must be chosen. Plots of data obtained are included.

72-73:08B-008
SELF-CLOSING IRRIGATION PIPE VALVE,
Haise, H. R., and Payne, M. L.
United States Department of Agriculture, Fort Collins, Colorado.

Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR3, p 517-522, September, 1972. 5 fig, 5 ref.
(See 72-73:04A-023)

72-73:08B-009
UNIFORM IRRIGATION WITH LOW-PRESSURE TRICKLE SYSTEMS.
Myers, L. E. and Bucks, D. A.
United States Water Conservation Laboratory, Phoenix, Arizona.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 98, No. IR3, p 341-346, September, 1972. 2 fig, 7 ref.
(See 72-73:03F-042)

72-73:08B-010
NUMERICAL SOLUTION OF MULTIPHASE WELL FLOW,
Brutsaert, W.
New Mexico Institute of Mining and Technology, Socorro, Department of Ground-Water Hydrology.
American Society of Chemical Engineers Proceedings, Journal of the Hydraulics Division, Vol. 99, No. HY11, Paper 10162, p 1981-2001, November 1973. 4 fig, 16 ref, append.

Descriptors: *Groundwater movement, *Water wells, *Drawdown, *Oil wells, Mathematical models, Finite element analysis, Simulation analysis, Porous media, Oil-Water interfaces.
Identifiers: *Multiphase flow.

A method is presented for numerically solving immiscible multiphase well flow considering three compressible fluids, two liquids, and one gas, and assuming isothermal conditions. Capillary and dissolution of gas in liquid are considered in the proposed mathematical model. Numerical difficulties arising from the nonlinearity of the equations and from the finite differencing in cylindrical coordinates are easily dealt with by using a modified Newton method to solve the fully implicit finite difference equations. Coning problems in the petroleum industry and unconfined flow problems in hydrology are typical applications.

72-73:08B-011
PROBLEMS AND SCS SPECIFICATIONS FOR LOW HEAD PVC PIPELINES,
Walter, C. L.
Soil Conservation Service, Bozeman, Montana.
Presented at Winter Meetings of the American Society of Agricultural Engineers, December 11-15, 1972, Chicago, Illinois. 23 p, 6 fig, 3 tab, 2 ref.

Descriptors: *Pipelines, *Plastic pipes, Plastic deformation, Hydraulic structures, Construction, Deformation, Failures, Specifications.

Survey conducted of low head PVC pipeline installations and further evaluation of the systems that failed point out the importance of following every requirement specified in the design and installation of these systems. Properties of low head plastic pipe are discussed, and SCS Standards and Specifications for its use are included.

Section XXVIII

ENGINEERING WORKS

HYDRAULIC MACHINERY (Group 08C)

72-73:08C-001
DEEP PLOWING - AN ENGINEERING APPRAISAL,
James, P. E., and Wilkins, D. E.
United States Department of Agriculture, Agricultural Research Service, Beltsville, Maryland.
Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 3, p 420-422, May-June, 1972. 5 f g, 4 tab, 4 ref.

Descriptors: *Cultivation, *Soil management, *Deep tillage, Farm management, Root zone, Soil treatment, Radioactivity.
Identifiers: Deep plowing.

Tests to determine the benefits and costs of deep plowing were conducted under six different sets of conditions. Questions to be answered were; limitations of deep plowing, power requirements, plow modifications needed, and soil burial pattern. Results ranged from almost no benefit to nearly double yields. Answers to the questions are as varied as the field conditions. The need for deep plowing should be evaluated at each location. It is not a solution to all problems.

72-73:08C-002
A TRACTOR-MOUNTED HYDRAULICALLY-OPERATED SOIL SAMPLER FOR RAPID SOIL CORING,
Schickedanz, D. M., Onken, A. B., Cummings, T., and Jones, R. M.
Texas A & M University, Agricultural Experiment Station, Lubbock.
Agronomy Journal, Vol. 65, No. 2, p 339-340, March-April, 1973. 2 fig.

Descriptors: *Core drilling, *Cores, Hydraulic equipment, Soil profiles.

A tractor-mounted hydraulically-operated soil sampler has been developed that incorporates a number of features required for extensive soil sampling. Speed, adaptability, mobility, accessibility, and safety are advantages of this equipment which are not all sufficiently adequate in currently available models.

Section XXXIX

ENGINEERING WORKS

SOIL MECHANICS (Group 08D)

72-73-08D-001
A LARGE, UNDISTURBED, WEIGHING LYSIMETER FOR GRASSLAND STUDIES,
Armiho, J.D., Twitchell, G.A., Burman, R.D., and Nunn, J.R.
Wyoming University, Laramie.
Transactions of the American Society of Agricultural Engineers, Vol 15,
No 5, p 827-830, September-October, 1972. 6 fig, 7 ref.
(See 72-73:02G-031)

72-73:08D-002
PREDICTING OPTIMUM DEPTH OF PROFILE MODIFICATION BY DEEP PLOWING FOR
IMPROVING SALINE-SODIC SOILS,
Rasmussen, W.W., and McNeal, B.L.
United States Department of Agriculture, Kimberly, Idaho.
Soil Science Society of America Proceedings, Vol 37, No 3, p 432-437,
May-June, 1973. 2 fig, 3 tab, 14 ref.
(See 72-73:02G-134)

72-73:08D-003
BULK DENSITY OF A FRAGIPAN SOIL IN NATURAL AND DISTURBED PROFILES,
Fritton, D.D. and Olson, G.W.
Pennsylvania State University, Agronomy Department, University Park
Soil Science Society of America Proceedings, Vol 36, No 4, p 686-689,
July-August, 1973. 3 tab, 7 ref.

Descriptors: *Soil physics, *Soil density, Soil compaction, Soil horizons, Soil profiles, Soil properties, Soil structure, Soil texture, Soil types, Soils.

Bulk density of horizons and layers in soil profiles at two locations (for natural soil and soil above pipelines and tileline) showed that modification of the Erie channery silt loam fragipan by mechanical disturbance alone results in re-establishing dense soil layers in less than 11 years. Buried topsoil, however, was much less dense after 12 years.

Section XXXX

ENGINEERING WORKS

RAPID EXCAVATION (Group 08H)

72-73:08H-001
DELAYS IN THE OPERATION OF SUBSURFACE DRAINAGE TRENCHING MACHINES,
Fisk, S. D., Broughton, R. S., and Norris, E. R.
Quebec Ministry of Agriculture and Colonization, Buckingham, Quebec, Canada.
Canadian Agricultural Engineering, Vol. 14, No. 2, p 69-71, December, 1972.
1 fig, 2 tab, 3 ref.
(See 72-73:02G-171)

SCIENTIFIC AND TECHNICAL INFORMATION

ACQUISITION AND PROCESSING (Group 10A)

72-73:10A-001
A QUICK-WEIGHING LYSIMETER SYSTEM CHECK,
Middleton, J. E.
Washington State University, Irrigated Agriculture Research and Extension Center, Prosser.
Agricultural Engineering, Vol. 53, No. 7, p 14-15, July, 1973. 1 fig.

Descriptors: *Lysimeters, Instrumentation, Moisture meters, Moisture content, Soil water, Evapotranspiration.

A quick dynamic lysimeter sensitivity check has been developed in which a 5 gallon water-filled container is placed on top of the soil at the center of a lysimeter. A 1/32-inch ID copper tube is soldered into the base of the container to slowly drain the water from the container and away from the lysimeter. Any operational malfunction will be indicated by an irregularity in the plotted time:weight loss curve.

72-73:10A-002
RECORDING WATER USE BY MEANS OF DIGITAL EQUIPMENT,
Payne, L.F., and Schreiber, H. A.
Southwest Watershed Research Center, Tucson, Arizona.
Agronomy Journal, Vol. 64, No. 1, p 83-84, January-February, 1972. 1 fig.

Descriptors: *Water utilization, Measurement, Hydroponics, Data collections, Data storage and retrieval.

A device made of digital components is described that automatically (i) senses a discrete loss of water in individual hydroponic cultures; (ii) stores this information as identifying numbers in an 8 2-digit word memory; and (iii) displays this information on an electric typewriter at 1-minute intervals. As many as 16 readings a day can be obtained in a greenhouse, if the ratio of leaf area to water surface area is high enough. This equipment, then, gives a sensitive measurement of water use related to climatic, genetic, or physiologic treatments.

72-73:10A-003
REFLECTANCE DISCRIMINATION OF COTTON AND CORN AT FOUR GROWTH STAGES,
Gausman, H. W., Allen, W. A., Cardenas, R., and Richardson, A. J.
United States Department of Agriculture, Agricultural Research Service, Weslaco, Texas.
Agronomy Journal, Vol. 65, No. 2, p 194-198, March-April, 1973. 6 fig, 1 tab, 12 ref.

Descriptors: *Remote sensing, *Reflectance, Infrared radiation, Instrumentation, Surveys, Corn, Cotton.

Increasing leaf age of corn within four growth stages had little effect on near-infrared light reflectance than young leaves. Reflectance was linearly correlated with chlorophyll concentration for the four growth stages of corn at the 550-nm wavelength; the linear correlation of reflectance with chlorophyll for the four growth stages of cotton was significant at the 650-nm wavelength. The largest differences among reflectances of corn leaves of different ages within growth stages occurred when tassels were appearing in the leaf whorls; this may be the best time to discriminate corn from other vegetation with remote sensors. Reflectance differences among cotton leaves within the four growth stages were similar. Spectral wavelength intervals centered around the 680-, 850-, 1,650-, and 2,200-nm wavelengths provide for the optimum discrimination of vegetation.

Section XXXXII

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